

**Final Site Observational Work Plan
for the UMTRA Project Site
at Falls City, Texas**

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Prepared by
U.S. Department of Energy
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Executive Summary

The requirements for groundwater compliance for Uranium Mill Tailing Remedial Action (UMTRA) Project sites, including the Falls City site, are found in the Uranium Mill Tailings Radiation Control Act (42 USC §7901 *et seq.*) and the U.S. Environmental Protection Agency's Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings (40 CFR Part 192; 60 FR 2854).

Groundwater beneath the Falls City site was contaminated by uranium ore processing activities, open pit mining, and *in situ* solution leaching of tailings. Open pit mining occurred at the Falls City site before the milling activities. Local mines were on parcels A and B of the site. Also, the shallow groundwater in the mined areas is of naturally poor quality because of ore bodies in the aquifer matrix.

A total of 2.5 million tons (2.3 million tonnes) of uranium ore were extracted and processed on the site. An acid-leach, countercurrent-decantation solvent extraction system was used to extract and concentrate uranium. The Deweesville sandstone containing the uranium was mined, ground, and then agitated in a sulfuric acid solution. An organic solution (tertiary amine and kerosene) was added during the extraction circuit. The uranium was stripped from the organic solution with either a sodium carbonate or an acidified sodium chloride solution. The residue sands, sandy-slimes, and slimes from processing uranium ore (tailings) were left on the mill site.

During surface remedial action, an estimated 7.0 million tons (6.4 million tonnes) of uranium mill tailings and other contaminated materials were consolidated and stabilized on the site. The groundwater protection strategy at the Falls City disposal site for the UMTRA Surface Project was an application for supplemental standards, based on limited use groundwater in the uppermost aquifer. This water is not a current or potential source of drinking water. Groundwater from the uppermost aquifer (groundwater from the Deweesville/Conquista Members and the Dilworth Member) contains widespread ambient contamination resulting from naturally occurring conditions and from the effects of human activity not related to uranium milling operations (uranium exploration and mining activities). The groundwater cannot be effectively cleaned up for drinking purposes with treatment methods reasonably employed by public water supply systems. The U.S. Nuclear Regulatory Commission (NRC) and the state of Texas concurred with the groundwater protection strategy for the disposal site in September 1992. Surface remedial action in accord with 40 CFR Part 192 Subpart A was completed in April 1994.

The proposed groundwater clean-up compliance strategy at the Falls City site is to perform no remedial action based on application for supplemental standards because the groundwater in the uppermost aquifer is classified as limited-use groundwater. Limited-use groundwater includes groundwater that is not a current or potential source of drinking water because of widespread, ambient contamination that cannot be cleaned up using treatment methods reasonably employed by public water supply systems (40 CFR §192.11[e]).

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Appendices—will be provided upon request. Click [Don Metzler](#) or [Audrey Berry](#) to request.

Acronyms and Abbreviations

ac	acre
ACL	alternate concentration limit
cm/s	centimeter(s) per second
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FM	Farm-to-Market
ft	foot (feet)
ft/d	foot per day
GCAP	Groundwater Compliance Action Plan
in.	inch(es)
km	kilometer(s)
m	meter(s)
mm	millimeter(s)
MAP	UMTRA Groundwater Management Action Process
MCL	maximum concentration limit
mg/L	milligrams per liter
mi	mile
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
PEIS	Programmatic Environmental Impact Statement
PVC	polyvinyl chloride
RAP	Remedial Action Plan
RRM	residual radioactive materials
SOWP	Site Observational Work Plan
SWI	Susquehanna-Western, Inc.
TAC	Technical Assistance Contractor
TDS	total dissolved solids
TKA	Turk, Kehle & Associates
tpd	ton per day
U ₃ O ₈	uranium oxide
UMTRA	Uranium Mill Tailings Remedial Action
UMTRCA	Uranium Mill Tailings Radiation Control Act
USGS	U.S. Geological Survey

1.0 Introduction

Produced by the U.S. Department of Energy (DOE), this site observational work plan (SOWP) will be used to determine a site-specific approach to comply with the U.S. Environmental Protection Agency (EPA) groundwater standards at the Falls City Uranium Mill Tailings Remedial Action (UMTRA) Project site. The purpose of the SOWP is to recommend a site-specific groundwater clean-up compliance strategy at the Falls City UMTRA Project site. The Falls City SOWP presents a comprehensive summary of site hydrogeological data, delineates a conceptual model of the aquifer system, and discusses the origins of milling-related groundwater contamination. It also defines the magnitude of groundwater contamination, potential environmental and health risks associated with groundwater contamination, and targets a proposed compliance strategy.

1.1 Groundwater Compliance Strategy

The proposed groundwater compliance strategy for the Falls City site is no remediation, with an application for supplemental standards based on the following criteria:

- The shallow groundwater is considered limited-use groundwater. Limited-use groundwater is groundwater that is not a current or potential source of drinking water because widespread ambient contamination cannot be cleaned up with treatment methods reasonably employed by public water supply systems (60 FR 2854). However, EPA standards require the DOE to consider the impact of milling contamination on current or future beneficial uses of groundwater. In the site area, potential beneficial uses would be limited to watering livestock and gardens because the quality of naturally occurring groundwater is poor and the yield is low.

Section 2.0 describes the requirements for meeting standards at UMTRA Project sites. Sections 3.0 and 4.0 provide site-specific data that support the proposed groundwater compliance strategy. Section 5.0 justifies the proposed groundwater compliance strategy.

1.2 UMTRA Project Programmatic Documents

The programmatic documents that guide the SOWP include the *UMTRA Groundwater Management Action Process* (MAP) (DOE 1996b), the *Final Programmatic Environmental Impact Statement* (PEIS) (DOE 1996a), and the *Technical Approach to Groundwater Restoration* (DOE 1993a). The MAP states the mission and objectives of the UMTRA Groundwater Project and provides a technical and management approach for conducting the project. The Final PEIS is the programmatic decision-making framework for conducting the UMTRA Groundwater Project. DOE will follow PEIS guidelines to assess the potential programmatic impacts of the Groundwater Project, to determine site-specific groundwater compliance strategies, and to prepare site-specific environmental impacts analyses more efficiently. Technical guidelines for conducting the groundwater program are found in the *Technical Approach to Groundwater Restoration*.

1.3 Relationship to Site-Specific Documents

The surface remedial action plan (RAP) provides site characterization information (DOE 1992b). This information was updated in developing the SOWP to formulate the site conceptual model. If a groundwater compliance strategy requiring remedial action activities is selected for this site, a groundwater RAP will be prepared, otherwise a modification to the surface RAP will suffice.

In 1995, a baseline risk assessment was prepared (DOE 1995) identifying potential public health and environmental risks at the site. Potential risks identified in the risk assessment are considered in this SOWP to ensure that the proposed compliance strategy is protective of human health and the environment.

After identification of a proposed compliance strategy in the SOWP and described in the Groundwater Compliance Action Plan (GCAP), a site-specific National Environmental Policy Act (NEPA) document (e.g., environmental assessment) will be prepared to determine the potential impacts, if any, of implementing the proposed compliance strategy.

1.4 SOWP Revisions

This SOWP presents a summary of existing data, a conceptual model, and a recommended compliance strategy based on this conceptual model. Additional data were collected in late 1995. Twelve additional monitor wells were installed and two rounds of groundwater samples collected and analyzed to date. This final document presents the additional data, correlates the data to previous information, and updates the site conceptual model.

2.0 Regulatory Framework

This section identifies the requirements for selecting a groundwater compliance strategy for the Falls City, Texas, processing site to achieve compliance with Subpart B of the EPA health and environmental protection standards for uranium and thorium mill tailings (40 CFR Part 192), and the final rule to the standards published in 60 FR 2854.

2.1 Uranium Mill Tailings Radiation Control Act

The United States Congress passed the Uranium Mill Tailings Radiation Control Act (UMTRCA) (42 USC §7901 *et seq.*) in 1978 in response to public concerns about potential health hazards from long-term exposure to uranium mill tailings. The UMTRCA authorized DOE to stabilize, dispose of, and control uranium mill tailings and other contaminated materials at inactive uranium mill processing sites.

Title I of the UMTRCA designates 22 inactive processing sites for remediation. It directs the EPA to promulgate standards; mandates remedial action in accordance with these standards; stipulates that remedial action be selected and performed with the concurrence of the U.S. Nuclear Regulatory Commission (NRC), and in consultation with the states and Indian tribes; directs the NRC to license the disposal sites; and directs the DOE to enter into cooperative agreements with the affected states and Indian tribes. Title II applies to active uranium mills. Title III applies only to certain uranium mills in New Mexico. The UMTRA Project is responsible for administering only Title I of the UMTRCA.

In 1988, Congress passed the Uranium Mill Tailings Remedial Action Amendments Act (Amendments Act) (42 USC §7922 *et seq.*), authorizing the DOE to extend without limitation the time needed to complete groundwater remediation activities at the processing sites.

2.1.1 EPA Groundwater Protection Standards

The UMTRCA requires EPA to promulgate standards for protecting public health, safety, and the environment from radiological and nonradiological hazards associated with uranium processing and the resulting residual radioactive materials (RRM). On January 5, 1983, the EPA published standards (40 CFR Part 192) for RRM disposal and cleanup. The standards were revised and a final rule was published January 11, 1995 (60 FR 2854).

The standards address two groundwater contamination scenarios: future groundwater contamination that might occur from tailings piles after disposal, and the cleanup of contamination resulting from the milling process at the processing sites (60 FR 2854). The UMTRA Surface Project is designed to control and stabilize tailings and contaminated soil. The Groundwater Project addresses residual contamination at the processing sites and is regulated by Subparts B and C of the EPA standards.

Subpart B, "Standards for Cleanup of Land and Buildings Contaminated with Residual Radioactive Materials From Inactive Uranium Processing Sites," requires documentation that action at the former processing sites ensure the residual groundwater contamination meets any of the following three criteria:

- Background levels. Concentrations of constituents in nearby groundwater not contaminated by processing activities.
- Maximum concentration limits (MCL). Maximum concentrations set by the EPA for certain hazardous constituents in groundwater, specific to the UMTRA Project ([Table 2–1](#)).

- Alternate concentration limits (ACL). An alternate concentration limit for a hazardous constituent that does not pose a substantial hazard (present or potential) to human health or the environment as long as the limit is not exceeded. An ACL may be applied after considering options to achieve background levels or MCLs (60 FR 2867).

Table 2–1. Maximum Concentration of Inorganic Constituents for Groundwater Protection for UMTRA Project Sites

Constituent	Maximum concentration ^a
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Lead	0.05
Mercury	0.002
Molybdenum	0.1
Nitrate (as N)	10.0 ^b
Selenium	0.01
Silver	0.05
Combined radium-226 and radium-228	5 pCi/liter
Combined uranium-234 and uranium-238	30 pCi/liter ^c
Gross alpha-particle activity (excluding radon and uranium)	15 pCi/liter

^aConcentrations reported in milligrams per liter (mg/L) unless otherwise noted.

^bEquivalent to 44 mg/L nitrate as nitrate.

^cEquivalent to 0.044 mg/L, assuming secular equilibrium of uranium-234 and uranium-238.

pCi - picocuries.

Ref: 60 FR 2854.

Subpart B also allows natural flushing to meet the standards. Natural flushing allows natural groundwater processes to reduce the contamination in groundwater to acceptable standards (background levels, MCLs, or ACLs). Natural flushing must allow the standards to be met within 100 years. In addition, institutional controls to protect human health and an adequate monitoring program must be established and maintained during the period of natural flushing; institutional controls would prohibit inappropriate uses of the contaminated groundwater. The groundwater also must not be a current or projected source of municipal drinking water during the period of natural flushing, and beneficial uses of groundwater must be protected (60 FR 2867).

Subpart C, "Implementation," provides guidance for implementing methods and procedures to reasonably ensure the provisions of Subpart B are satisfied. Subpart C requires the following:

- The conditions of Subpart B must be met on a site-specific basis, using information gathered during site characterization and monitoring. The plan to meet the conditions of Subpart B must be stated in a site-specific groundwater compliance action plan. The plan must contain a compliance strategy and a monitoring program, if necessary (60 FR 2868).

Subpart B also describes the conditions under which DOE may apply supplemental standards to contaminated groundwater, rather than meeting background levels, MCLs, or ACLs. The standards define limited-use groundwater as groundwater that is not a current or potential source of drinking water because total dissolved solids (TDS) exceed 10,000 milligrams per liter (mg/L); widespread ambient contamination cannot be cleaned up using treatment methods reasonably employed by public water supply systems; the quantity of water available is less than 150 gallons (570 liters) per day; or because cleanup of groundwater would cause excessive environmental harm; or because cleanup is technically impractical (60 FR 2867). Subpart C requires the DOE to inform private owners and occupants of the area affected by hazardous constituents and to solicit their comments before applying supplemental standards. The DOE has implemented a public participation program in Falls City to meet the requirements of Subpart C.

The DOE proposes a no remediation/supplemental standards compliance strategy for the Falls City, Texas, site. This strategy will achieve compliance with the EPA groundwater standards applicable to Title I UMTRA Project sites. To protect groundwater and to achieve compliance with the EPA groundwater standards under Subpart A (UMTRA Surface Project), a narrative supplemental standard for the Falls City site was proposed and approved. The supplemental standard application for the surface remedial action was based on widespread ambient contamination that could not be cleaned up with methods reasonably employed by public water supply systems. Therefore, the DOE concluded that groundwater in the uppermost aquifer meets the widespread ambient contamination criteria of limited-use groundwater. The NRC and the state of Texas concurred with the DOE groundwater protection strategy for the UMTRA Surface Project in 1992. The Falls City groundwater compliance strategy (to meet Subpart B requirements) is identical to the Surface Project groundwater protection strategy. The regulatory drivers that guide the selection of the proposed groundwater compliance strategy for the Falls City, Texas, site and all other UMTRA sites are identified below.

2.1.2 Cooperative Agreements

The UMTRCA requires remedial action to include full participation of the states and Indian tribes that own land containing uranium mill tailings. The UMTRCA also directs DOE to enter into cooperative agreements with the states and Indian tribes.

2.2 National Environmental Policy Act

The UMTRCA is a major NEPA activity (42 USC §4321 *et seq.*). Regulations of the Council on Environmental Quality (to implement the NEPA) are codified in 40 CFR Part 1500; these regulations require each federal agency to develop its own implementing procedures (40 CFR §1507.3). The DOE-related NEPA regulations are contained in 10 CFR Part 1021, *National Environmental Policy Act; Implementing Procedures*. Guidance is provided in *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements* (DOE 1993b).

Pursuant to NEPA, in 1994 the DOE drafted a PEIS for the UMTRA Groundwater Project. The PEIS document was finalized in October 1996. The purpose of the NEPA document was to analyze the potential impacts of implementing four programmatic alternatives for groundwater compliance at the designated processing sites. The preferred alternative for the UMTRA Groundwater Project was published in a record of decision in 1997. All subsequent action on the UMTRA Groundwater Project must comply with the record of decision.

3.0 Summary of Additional Data Collected

3.1 Statement of Data Collected

The DOE evaluated existing site information and identified data gaps (uncertainties) that had been addressed to confirm the appropriateness of the proposed groundwater compliance strategy and the feasibility of alternative strategies if required. These “data gaps” are addressed in this Final SOWP.

Additional characterization data designed to reduce system uncertainties have been collected. These additional data enhance the understanding of site conditions and ensure the appropriate groundwater compliance strategy is implemented.

3.1.1 Qualitative Analysis of Background Groundwater Quality

Background groundwater quality in the Deweesville/Conquista aquifer has been sufficiently characterized to demonstrate that it qualifies for a supplemental standard application (DOE 1992). However, a literature search and a review of groundwater quality data from monitor wells and other wells located near the site was conducted to demonstrate qualitatively that the supplemental standards are protective of potential beneficial uses of groundwater in the site vicinity. Results of the review of the groundwater quality data are presented in the *Final Baseline Risk Assessment* (DOE 1995) and in the Validated Data Packages (DOE 1996c and 1997) for the most recent rounds of groundwater sampling conducted in January 1996 and January 1997.

3.1.2 Land and Water Use Survey

The DOE has demonstrated that the groundwater compliance strategy will protect human health and the environment and protect potential beneficial uses of the groundwater. To evaluate the health risks and environmental impacts associated with groundwater contamination, investigators identified potential exposure pathways within and downgradient from the contaminated zones and further assessed the likelihood of direct or indirect human contact with contaminated groundwater through the exposure pathways. Results of the land and water use survey are presented in the *Final Baseline Risk Assessment* (DOE 1995). The land and water use survey expanded the area of the previous survey, which was conducted within a 2-mile (mi) (3-kilometer [km]) radius of the site. The latest survey covers an area that extends well beyond the current, known lateral extent of groundwater contamination ([Figure 3-1](#)). Locations of other wells identified in the latest survey are presented in Plate 3. During the land and water use survey, the following activities were conducted:

- A literature search and review of groundwater quality data from existing wells to further define background groundwater quality.
- A well record search by reviewing appropriate files from the state of Texas. The well records help determine well construction information, depth to water, well productivity information, and water quality.
- Review of aerial photography of the region to quickly locate and identify stock ponds that could be used to water livestock.

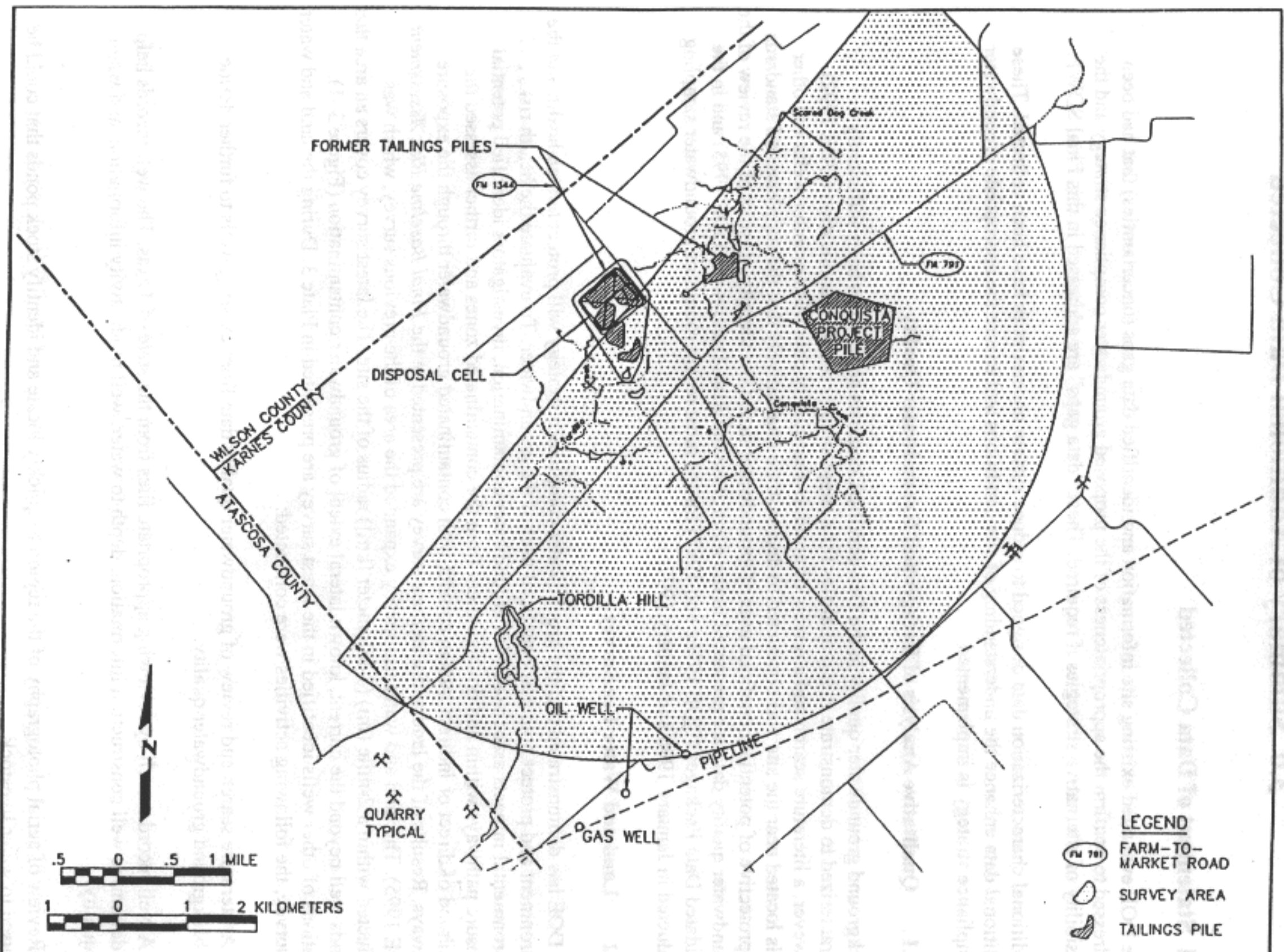


Figure 3-1. Areal Coverage of Land and Water Use Survey

- A door-to-door survey to interview local landowners regarding past and present land and water use. Domestic wells and stock ponds were located and sampled, if possible. Depth-to-water was measured in domestic wells.

3.1.3 Hydrogeologic Investigations

Installing Monitor Wells and Groundwater Sampling

DOE installed twelve additional monitor wells at the site to further define the extent and magnitude of contamination in the uppermost aquifer, refine the understanding of groundwater flow direction(s), further assess the potential affects of the contamination on other aquifers, and further assess potential beneficial uses of those aquifers. Monitor well construction details and lithologic information are provided in Appendix A. The location of each new monitor well is shown in [Figure 3–2](#).

- Monitor well 883 was installed at a location southeast of the disposal cell and southeast of Farm-to-Market (FM) Road 791 to further characterize the downgradient extent of contamination in the Deweesville/Conquista aquifer that is associated with the former tailings piles 1, 2, 4, 5, 6, and 7.
- Monitor wells 884, 885, 886, and 887 were installed to further characterize the extent of groundwater contamination in the Deweesville/Conquista aquifer associated with former tailings pile 3. These monitor wells are located south and east of former tailings pile 3 and north of FM 791.
- Monitor well 888 was completed in the Dilworth aquifer east of former tailings pile 3 to verify that contamination has not reached the Dilworth aquifer in this area.
- Monitor wells 889, 890, and 891 were installed north of former tailings pile 3 to further characterize the extent of groundwater contamination in the Dilworth aquifer along Scared Dog Creek.
- Monitor well 892 was completed in the Conquista and Deweesville aquifer to further characterize the downgradient extent of contamination south of the disposal cell along Tordilla Creek.
- Monitor well 893 was installed at a location downgradient from former tailings pile 4 near the former location of monitor well 833. Abandoned during surface remediation activities, well 833 is believed to have been improperly completed in the Dilworth aquifer, thus water samples collected from well 833 have shown evidence of mill-related contamination. Monitor well 893 was completed in the Dilworth aquifer to evaluate if mill-related contamination is present in the Dilworth aquifer in this area.
- Monitor well 894 was completed in the Deweesville and Conquista aquifer, next to the existing Deweesville/Conquista well 880, to serve as an observation well during a proposed aquifer test.

Water Level Monitoring

During routine groundwater sampling, the depth to water in monitor wells completed in the uppermost aquifer was measured to observe short- and long-term fluctuations in groundwater levels and to evaluate the rate of groundwater mound dissipation immediately downgradient of the disposal cell. Potentiometric contour maps of the groundwater surface for the Deweesville/Conquista and Dilworth aquifers, measured during the January 1997 sampling campaign, are presented in Section 4.0.

Core/Analysis

Core analysis for porosity, bulk density, grain size analysis, and saturated hydraulic conductivity was conducted on selected samples to provide more detailed, small-scale information on aquifer characteristics. Core tests relate the parameters determined on a small portion of the aquifer (cubic centimeters) to the macroscopic behavior of the aquifer (cubic kilometers). Results of the tests conducted by Daniel B. Stephens & Associates, Inc., are provided in Appendix B.

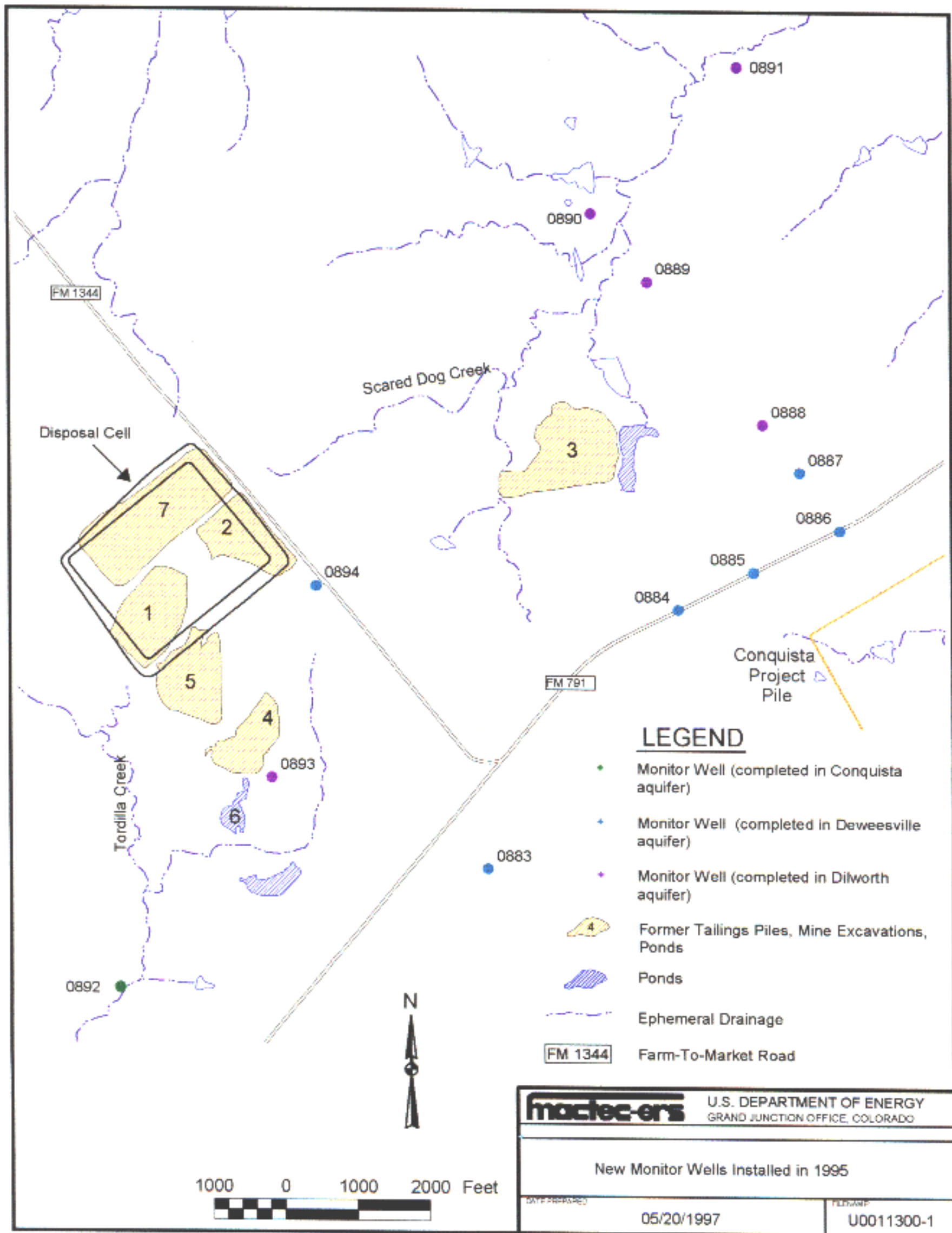


Figure 3-2. New Monitor Wells Installed in 1995

4.0 Site Conditions

This section discusses past uranium mining and milling activities at and in the vicinity of the Falls City site, the surface remedial action, and the status of surface cleanup efforts. Site characterization data are summarized and the site conceptual model is presented. The site conceptual model is based on groundwater characterization data and is intended to enhance the understanding of the extent and magnitude of contamination, exposure pathways, and risk to public health and the environment. The model also provides the rationale for the proposed groundwater compliance strategy.

Hydrogeologic and geochemical characterization activities at the Falls City site began before surface cleanup and continued throughout surface remedial action (Falls City Site Technical Notebook, January 1995). Thus, sufficient data are available to develop a conceptual model for the former processing site. Section 4.3 presents the conceptual model and discusses the nature and extent of the groundwater contamination based on the most recent rounds of groundwater sampling conducted in January 1996 and January 1997.

4.1 Site History

4.1.1 Physical Setting

The Falls City site is in Karnes County, Texas, approximately 8 mi (13 km) southwest of the town of Falls City and 46 mi (74 km) southeast of San Antonio, Texas (Figure 4-1). Before surface remedial action, the tailings site consisted of two parcels. Parcel A consisted of the mill site, one mill building, five tailings piles, and one tailings pond south of FM Road 1344 and west of FM 791. A sixth tailings pile, designated Parcel B, was north of FM 791 and east of FM 1344 (Figure 4-2).

4.1.2 Land and Water Use

Most of the land surrounding the former processing site is used for cattle grazing and dry farming. Local residents primarily grow hay and other livestock feed crops. Most livestock in the site area are beef cattle; some residents keep small poultry flocks.

The Deweesville/Conquista and the Dilworth aquifers are not used as domestic or potable water supplies in the site vicinity, although the Dilworth aquifer is occasionally used within a 2-mi (3-km) radius of the site to water stock (DOE 1992). The Three Oaks Water Company supplies residences within the site area with water from a Carrizo Sandstone well. This well is 2,000 feet (ft) (600 meters [m]) deep and is approximately 10 mi (16 km) northwest of the site. Livestock are watered primarily from surface collection tanks or stock ponds.

4.1.3 History of Operations

In late 1955, the Climax Molybdenum Company identified uranium ore deposits averaging 0.20 percent uranium oxide (U_3O_8) in an area 8 mi (13 km) west of Falls City. Open-pit mining occurred from 1959 to 1960 and was completed when Susquehanna-Western, Inc. (SWI) acquired the property as a mill site in 1961. Open-pit mining occurred at the former locations of piles 3, 4, 5, and 6. The mill was constructed as a nominal 300-ton-per-day (tpd) operation, but operated at 220 tpd from April 1961 until early 1968 (Merritt 1971). In 1968, the mill expanded to operate at 900 tpd and, for short periods, up to

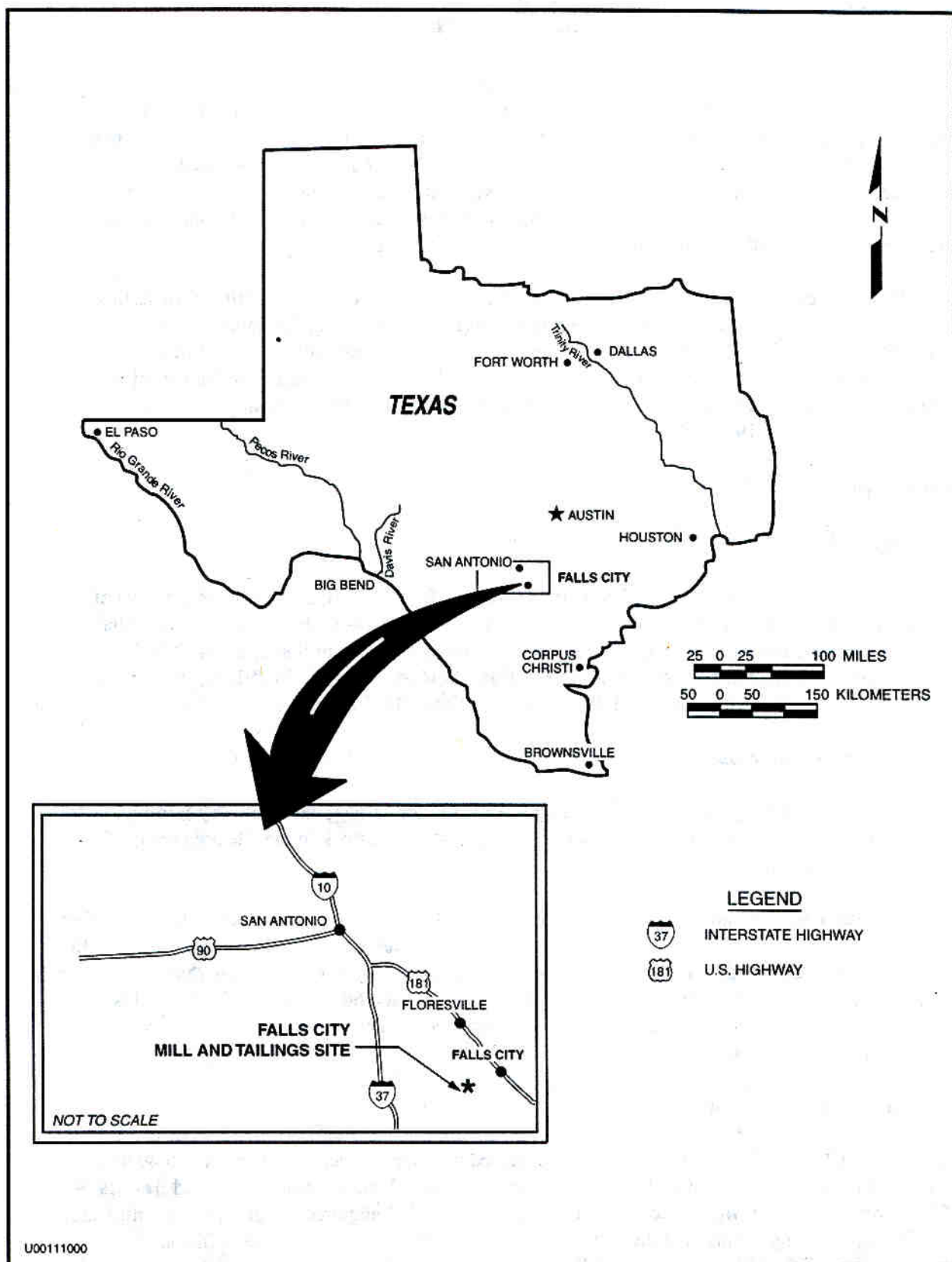


Figure 4-1. Location of the Falls City, Texas, Site

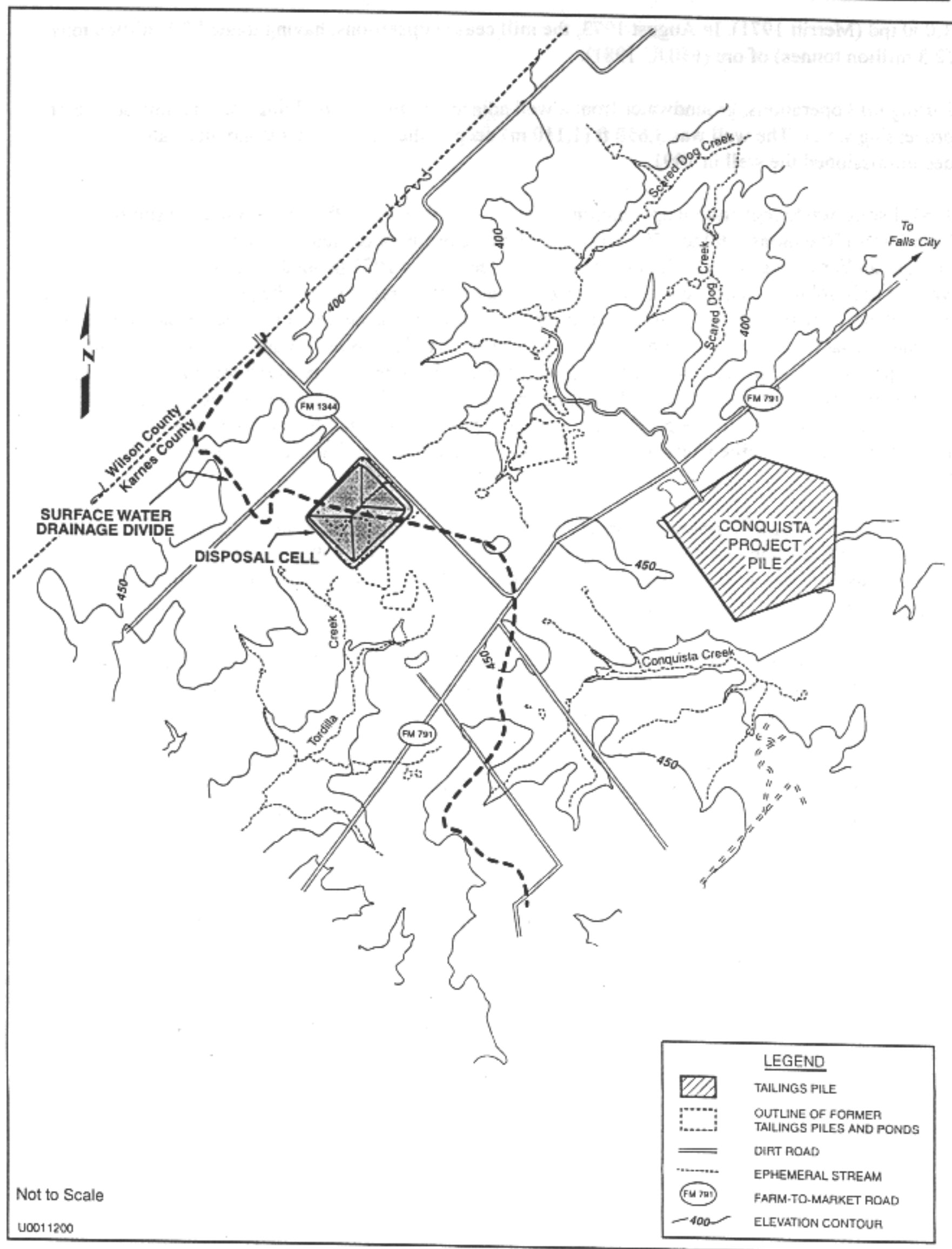


Figure 4-2. Topographic Map of the Disposal Site Area, Falls City, Texas, Site

1,000 tpd (Merritt 1971). In August 1973, the mill ceased operations, having treated 2.5 million tons (2.3 million tonnes) of ore (FBDU 1981).

During mill operations, groundwater from a well adjacent to the mill building was the only source of processing water. The well was 3,650 ft (1,110 m) deep in the Carrizo Sandstone; the state decommissioned the well in 1991.

A SWI solid waste registration application submitted in 1973 stated that fresh water consumption ranged from 50 to 150 gallons (190 to 570 liters) per minute. Consumption depended on the ore, amount of rainfall, and/or tailings pond solution available for recycle (in 1973 ponded water from tailings pile 7 was the only solution in active use), and reagent consumption required by the process. SWI also stated in the application that "75 gpm [gallons per minute] fresh water consumption may be considered a fair average." That measurement represents a net discharge to tailings pile 7 of approximately 121 acre (ac)-ft per year. The ponds on the tailings piles were not lined, but sumps along the pile perimeters pumped runoff and seepage back to the tailings piles. During mill operation (1961 to 1973), approximately 865 ac-ft of ore-processing water and precipitation that fell on the ponds might have infiltrated the Deweesville/Conquista aquifer. This calculation is included as Appendix C to this document.

At the completion of SWI operations in 1973, a 40-ac (16-hectare [ha]) pond had been created at the top of pile 7. The liquids in this pond were acidic raffinates. In August 1978, Solution Engineering, Inc., of Alice, Texas, initiated *in situ* extraction mining on the tailings piles, installing an injection/withdrawal system in pile 7. Fluids from the raffinate pond were injected to a depth of 30 to 45 ft (9 to 14 m) at a rate of about 500 gallons (1,900 liters) per minute. Between 300 and 550 gallons (1,140 to 2,100 liters) per minute of fluids were extracted from the pile; those uranium-bearing solutions were processed at the mill. Eventually, the operation expanded to piles 1, 2, 4, and 5. *In situ* solution mining ended in February 1982. In 1983, after 3.5 years of leaching operations, the state of Texas annulled Solution Engineering's operating license and directed the company to conduct interim restoration activities. Interim restoration consisted of spray-evaporating the large ponds on top of piles 7 and 2, capping piles 7 and 2 with a 1- to 2-ft (0.3- to 0.6-m)-thick clay cover, and dismantling the mill. The interim restoration was completed in 1986 and probably reduced the rate of pore fluid seepage into the aquifer (DOE 1992).

4.1.4 Milling Process

An acid-leach countercurrent-decantation solvent-extraction system extracted and concentrated the uranium (as U_3O_8). This process is described below (Merritt 1971).

Sulfuric acid was added as a leaching agent to the ore slurry, producing a slurry with a pH near 1.0. A five-stage, countercurrent washing circuit included a polyacrylamide-type flocculent to assist in separating the slimes from the process stream. The solvent extraction circuit included an organic solution containing 7.5 percent tertiary amine and 2.5 percent isodecanol in kerosene. Uranium was stripped from the loaded organic with either a sodium carbonate or acidified sodium chloride solution. The final uranium product ("yellow cake") was precipitated by adding caustic soda.

4.1.5 Surface Remedial Action

Remedial action consolidated and stabilized 7.0 million tons (6.4 million tonnes) of tailings and contaminated materials into a disposal cell covering 132 ac (53.4 ha) in the vicinity of piles 7 and 2. The approximate footprint of the cell is 2,600 x 2,200 ft (790 x 670 m). At least 30 monitor wells within or around the construction area were decommissioned (cutoff and grouted) during surface remedial action.

The DOE is required to demonstrate that RRM surface cleanup and disposal will not impact (or further impact) groundwater in the vicinity of the former processing site. Thus, the NRC required the site-specific RAP to include a groundwater protection strategy.

To protect the groundwater and achieve compliance with the EPA groundwater standards, a narrative supplemental standard for the Falls City site was proposed. The supplemental standard for the surface remedial action was based on widespread ambient contamination that could not be cleaned up using methods reasonably employed by public water supply systems. Also, there were few potential beneficial uses of the groundwater due to poor quality and low yield. Historically, the uppermost aquifer has not been used as a drinking water source for those two reasons. Because the groundwater quality is so poor (TDS 7,500 mg/L) in the upper aquifers, they are rarely used except as a water source for limited stock watering and occasional home garden irrigation. Therefore, groundwater in the uppermost aquifers meets the widespread ambient contamination criterion of limited-use groundwater (DOE 1992).

The NRC and the state of Texas concurred with the surface RAP and groundwater protection strategy in September 1992. Surface remedial action was completed in May 1994.

4.2 Sources of Existing Data

The UMTRA Project and other investigators conducted several hydrologic, geologic, and geochemical studies at and in the vicinity of the Falls City processing site.

In a U.S. Geological Survey (USGS) report based largely on data from the exploratory drilling programs conducted in the late 1950s, Bunker and MacKallor (1973) describe the geology of uranium ore deposits in the Falls City area. The USGS report includes detailed discussions of the stratigraphy and mineralogy of several ore deposits in the Tordilla Hill-Deweeseville area, including the two deposits (Nuhn and Luckett) mined at the Falls City site (open pit mines).

Kallus (1975) prepared a report for EPA Region VI on the general environmental impacts of uranium mining and milling in the South Texas uranium district. That report summarizes surface and groundwater monitoring data compiled from USGS and Texas Water Quality Board records. Groundwater data were derived from approximately 100 samples, with complete chemical analyses performed on one-third of the samples. Kallus found highly variable natural levels of radioactivity, arsenic, molybdenum, and selenium in South Texas groundwater. The only reported health impact from uranium mining was molybdenosis in cattle that grazed in runoff-contaminated areas near overburden piles.

Turk, Kehle & Associates (TKA) conducted the first site-specific hydrogeologic study at the Falls City mill site in 1976 (TKA 1976). This study was a reconnaissance-level investigation that relied on existing water level and water quality data from 26 monitor wells around the site and included a general characterization of the local climate, geology, surface water quality, and groundwater conditions. The TKA study concluded radioactive contamination (gross alpha and beta activity) was not evident in the aquifer system beneath the site.

Ford, Bacon & Davis Utah, Inc. (FBDU 1981) prepared an engineering assessment of the Falls City site that included field sampling of the 14 monitor wells installed by Solution Engineering, Inc. around the tailings piles. Analyses of samples from these wells indicated contamination of the shallow aquifer in the vicinity of the tailings piles.

In 1983, Geochemistry and Environmental Chemistry Research, Inc. (GECR 1983), initiated a geochemical investigation of the Falls City site. Approximately 50 surface water and soil core samples were analyzed to define the extent of surficial contamination on and around the tailings piles. However, only two wells in the vicinity of the site were sampled.

The recent site characterization program conducted by the UMTRA Project included a four-phase hydrogeologic field investigation. In the first phase (December 1985 through May 1986), 39 new 4-inch (in.) (100 millimeter [mm]) polyvinyl chloride (PVC) cased monitor wells were installed and sampled; 25 existing wells were sampled as well.

The second phase of the investigation (December 1988 through March 1990) was designed to gather supplemental data from the site to fill data gaps and achieve full compliance with the EPA groundwater protection standards. In addition, 12 more monitor wells were installed at depths ranging from 40 to 230 ft (2 to 70 m), completed primarily in the Dilworth Sandstone Member and the upper Manning Clay Formation; groundwater from 50 to 55 monitor wells was sampled, including the 12 new wells and selected Conoco background wells in the site vicinity; and 16 lysimeters were installed to characterize the water quality of tailings fluids in piles 1, 2, 4, 5, 7, and pond 6.

Between 1990 and 1992, with the assistance of the Texas Bureau of Economic Geology, the UMTRA Project conducted a third phase of the field program to further characterize site geochemistry. The program included drilling 13 coreholes, analyzing the geochemistry of the cores, and installing 17 new monitor wells.

In 1991 and in early spring of 1994, domestic well surveys were conducted in a 2-mi (3-km) radial area centered upon the site. The survey determined the historical and current use of groundwater in the Deweesville/Conquista and Dilworth aquifers. Plate 3 shows locations of all wells drilled or sampled by the DOE at the Falls City site.

During the final phase in late 1995, twelve additional monitor wells were installed to: 1) refine the conceptual model of the groundwater flow system, 2) further quantify the extent and magnitude of groundwater contamination at the site, and 3) determine aquifer characteristics by analyzing core samples for porosity, hydraulic conductivity, particle size characteristics, and bulk density.

4.3 Conceptual Site Model

A conceptual model of the site was developed to understand the site and to support the proposed groundwater compliance strategy and remediation objectives. The conceptual model is summarized below. [Figure 4-3](#) shows the locations of all the monitor wells used to develop the model. Sections 4.3.1 through 4.3.5 provide details of the model.

Two low-yield (generally less than 1 gallon [4 liters] per minute) aquifers underlying the site have been identified: the Deweesville/Conquista and the Dilworth. The Deweesville and Conquista Members are grouped together as one aquifer because no continuous impermeable strata separates them and exploration drilling during past uranium mining left boreholes that may not have been thoroughly decommissioned.

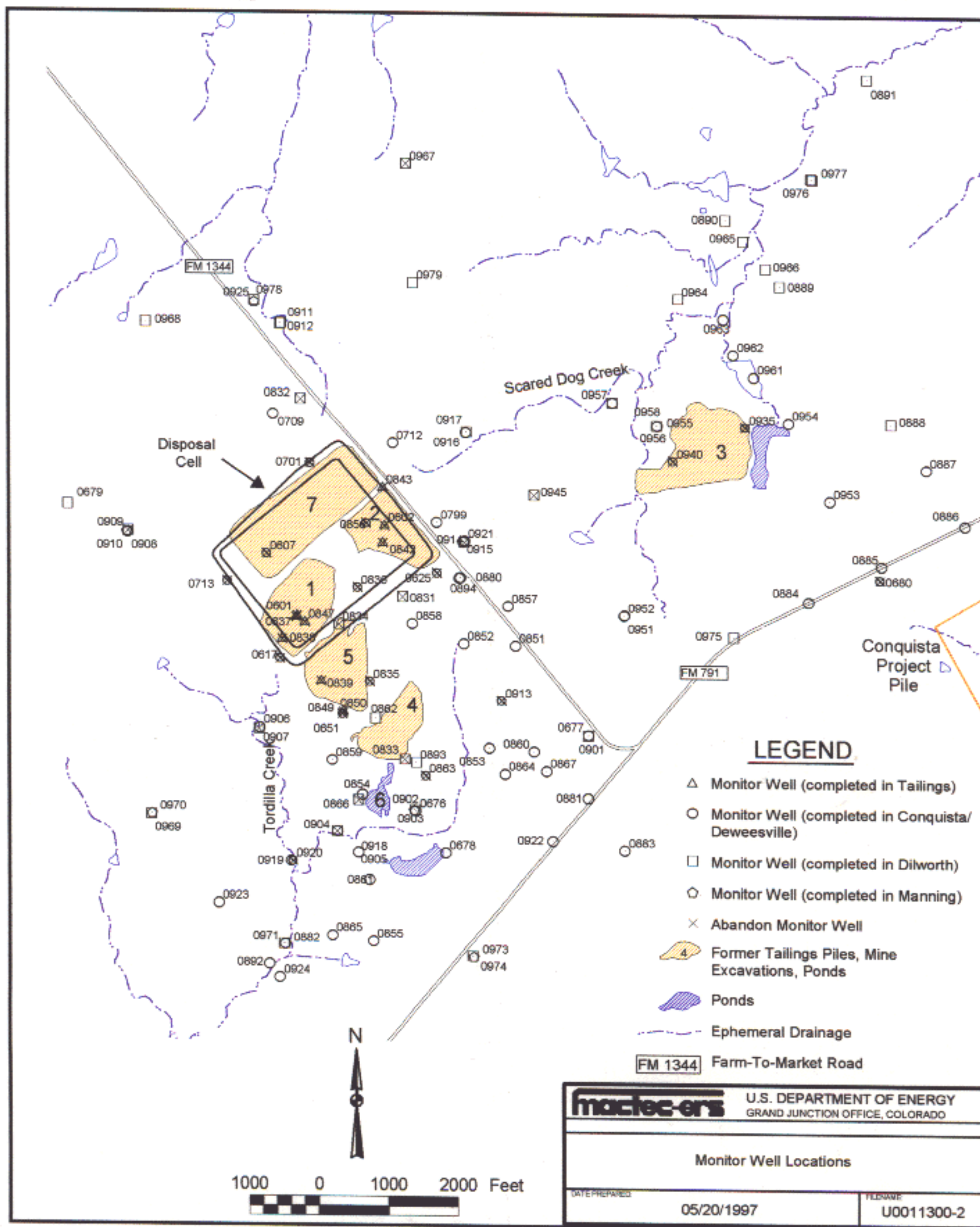


Figure 4-3. Monitor Well Locations

Several investigators, including the Technical Assistance Contractor (TAC) and the Texas Bureau of Economic Geology, concluded the upper portions of the Deweesville/Conquista Formations (the subsurface at the processing site) historically were unsaturated, and milling and *in situ* mining activities caused the current saturated conditions beneath the site. The TAC and the Texas Bureau of Economic Geology determined that processing and mining water created a ground water mound under the site and that ground water from the mound moved radially outward and downdip. The TAC used MODFLOW (USGS 1988) to simulate groundwater flow at the site; preliminary modeling results support the hydrologic representation of site conditions suggested by the TAC and Texas Bureau of Economic Geology.

The principal ore-bearing unit at the site is the Deweesville Sandstone. Because the uranium mineralization associated with the ore bodies causes background ground water quality in both the Deweesville/Conquista and Dilworth aquifers to vary with depth and location, the ground water quality is difficult to define deterministically. Thus, the understanding of geochemical conditions at the site is best described qualitatively. Contaminants of concern in the aquifer that are related to the mill processing have been identified.

4.3.1 Hydrogeologic Setting

The Falls City site is on the coastal plain of the Gulf of Mexico. The main topographic element in the Karnes County area is a series of ridges trending predominantly northeast to southwest. These ridges are mainly *cuestas* (sloping plains) formed by resistant gulfward-dipping strata, although some river terrace gravels also form local topographic highs. Small intermittent streams follow the easily eroded strata between *cuestas*, producing a pronounced northeast trend in the drainage pattern in the site area. Relief from ridges to intervening drainage pathways is generally less than 100 ft (30 m) (TKA 1976). Figure 4–2 presents a topographic map of the site area.

Mean annual precipitation in the site area is 30 in. (760 mm) (NOAA 1979). Virtually all measurable precipitation is in the form of rain, which reaches monthly maxima in both May and September (NOAA 1979). Most precipitation occurs as heavy rainfall during brief thunderstorms, which causes great spatial and temporal variability in rainfall distribution.

The Falls City site is underlain by clastic sedimentary strata that dip gently southeast (approximately 20 ft per 1,000 ft) as part of the thick homoclinal sequence of the Gulf Coastal Plain. The local sedimentary strata are comprised of generally un lithified sand, silt, and clay deposits of the Whitsett and Manning Clay Formations. The site rests on outcrops of the Dubose Clay, Deweesville Sandstone, and Conquista Clay Members of the Whitsett Formation (Plate 1). Tailings were placed in several old open pits excavated through the ore-bearing Deweesville and upper Conquista Members. Underlying the Conquista Clay is the Dilworth Sandstone Member, which, in turn, overlies the Manning Clay Formation. The Manning Clay is the oldest geologic unit encountered during the site drilling program. The site is located on a groundwater divide. This divide is oriented west-northwest through the disposal cell area.

Three low-yield water-bearing strata are within the upper 200 ft (60 m) of the Whitsett Formation sediments underlying the site. These water-bearing strata in descending order are the Deweesville Sandstone Member, the Conquista Clay Member, and the Dilworth Sandstone Member. The Conquista Clay Member is composed of three subunits: an oxidized upper Conquista Clay/silt, the Conquista Sandstone, and a lower Conquista Clay (Plate 2). The Conquista Sandstone extends downdip into the subsurface but thins significantly and becomes considerably finer-grained. The Deweesville Sandstone Member, upper Conquista Clay, and Conquista Sandstone subunits are grouped together as one aquifer because continuous impermeable strata do not separate the members, with no apparent restrictions in groundwater movement between the two members. Although the Deweesville/Conquista and Dilworth

are referred to as aquifers in this document, these members have never been developed as a source for drinking water supply because of their low yield (generally less than 1 gallon [4 liters] per minute) and poor water quality.

4.3.1.1 Deweesville/Conquista Aquifer

Shallow groundwater in the site vicinity is found in the Deweesville/Conquista aquifer at depths of 5 to 30 ft (2 to 9 m) below land surface. Groundwater within the aquifer occurs under unconfined conditions in the northern and western portions of the site vicinity and along creek beds. In areas where the Deweesville/Conquista aquifer is unconfined, the potentiometric surface generally is a subdued replica of the surface topography. The saturated condition of the Deweesville/Conquista in the immediate vicinity of the disposal cell is due, in part, to the discharge of past milling-process water.

The top of the lower Conquista Clay defines the lower boundary of the Deweesville/Conquista aquifer. The intersection of the Deweesville/Conquista water table and the top of the lower Conquista Clay marks the approximate updip limit of saturation in the Deweesville/Conquista aquifer (Plate 2). Because the former tailings piles were located on the updip surface of the Deweesville Sandstone and the upper Conquista Clay outcrops, it is impossible to install upgradient, background monitor wells screened in the Deweesville/Conquista aquifer.

Groundwater within the Deweesville/Conquista aquifer is recharged by infiltrating precipitation in the Deweesville/Conquista outcrop areas (Plate 1), past seepage of tailings fluids, and interformation leakage in downdip areas. As shown on the potentiometric surface contour map developed from water level measurements collected in 1997 (Figure 4-4), groundwater from the former tailings piles flows in three directions: east, away from former tailings pile 2; south, toward the eastern tributary of Tordilla Creek; and southeast, down the structural dip of the Deweesville beneath FM 791 and into the deeper subsurface.

Seepage from tailings disposed of in old pits and on the outcrop of the Deweesville Sandstone and upper and middle Conquista members has resulted in a groundwater mound in the Deweesville/Conquista aquifer (Figure 4-4). The Deweesville/Conquista potentiometric surface beneath tailings piles 1, 2, 4, and 5 is higher than background groundwater levels. Groundwater levels near the tailings have risen since initial mining. Before milling and tailings disposal activities, there was little water in the Deweesville/Conquista from the tailings area down to the tributary of Tordilla Creek (BEG 1992). A review of the scientific literature on this site suggests this zone of the Deweesville/Conquista might have contained very little water prior to milling activity. The floor of open pit mine 5 (former tailings pile 5) extended several feet below the Deweesville/Conquista interface; a 1960 photograph of this pit (Bunker and MacKallor 1973) shows the contact between the Deweesville and the Conquista was dry. After these pits were filled with saturated tailings and the later leachate injection/*in situ* leaching began, large volumes of tailings pore water were introduced to the Deweesville/Conquista. Consequently, a groundwater mound developed on the processing site in and around the tailings piles. Currently, the water table in the outcrop area of the Deweesville is 8 to 17 ft (2 to 5 m) above the base of the Deweesville. The Conquista Clay also was affected by these milling-related processes and water levels beneath pile 7 (on the Conquista outcrop) may have been as much as 40 ft (10 m) higher than the background water table elevation (BEG 1992). Background groundwater conditions do not exist in the outcrop area of the Deweesville Sandstone immediately east of the site. Naturally occurring groundwater might only exist where the Deweesville/Conquista aquifer dips below the Dubose Clay (BEG 1992).

4.3.1.2 Dilworth Aquifer

The Dilworth aquifer is a sandstone member of the Whitsett Formation. Groundwater is unconfined north of the site where the Dilworth sandstone is recharged at the outcrop (Plate 1). A potentiometric surface map of the Dilworth aquifer is shown in [Figure 4–5](#) using water level measurements collected in January 1997. In general, the groundwater flows along strike in the recharge area. Depth to groundwater in the Dilworth aquifer is approximately 100 ft (30 m) below ground level in the area where the disposal cell is located. Down dip to the southeast, groundwater in the Dilworth aquifer becomes confined by the lower Conquista clay.

The Dilworth aquifer is separated from the Deweesville/Conquista aquifer by 30 to 50 ft (9 to 15 m) of carbonaceous clay of the lower Conquista Clay subunit, which acts as an aquitard to downward seepage. A downward hydraulic gradient occurs between the Dilworth aquifer and the overlying Deweesville/Conquista aquifer.

The Texas Bureau of Economic Geology identified three discrete potentiometric highs as an indication of leakage from the Deweesville/Conquista aquifer into the Dilworth aquifer. These leakages were caused by extensive deep drilling by mining companies exploring for ore. The potentiometric highs are near monitor wells 901, 915 and 917, and 905 and 907. The mining exploration programs drilled approximately 370 boreholes that typically penetrated through the Dilworth and were not abandoned properly (BEG 1992). The monitor wells were constructed with the filter pack interval placed across the Conquista/Dilworth contact. The elevated water levels might be influenced by drainage from the Deweesville/Conquista aquifer through the well bore annulus rather than drainage through the formations. The Dilworth is underlain by the carbonaceous clays and lignite seams of the Manning Clay Formation which effectively forms a 300-ft (90-m)-thick aquitard.

Because improperly abandoned exploratory boreholes create a potential hydraulic interconnection between the Deweesville/Conquista aquifer and the Dilworth aquifer, the Dilworth Sandstone Member is included as part of the uppermost aquifer.

4.3.1.3 Hydraulic and Transport Properties

The saturated hydraulic conductivities of the most permeable beds of the Whitsett Formation aquifer system, as determined by aquifer tests and single-packer pressure testing, range from approximately 0.5 to 2.6 ft per day (ft/d) (1.8×10^{-4} to 9.0×10^{-4} centimeters per second [cm/s]). The TAC conducted this aquifer test (and all other aquifer tests discussed here) in the spring of 1991. The hydraulic conductivities are consistent with the ranges generally reported in the hydrologic literature for sandy clays, silty to clayey sands, and fine sandstones. The sandy members contain a high percentage of silts and clays, and yield small amounts of water (1 to 2 gallons [4 to 8 liters] per minute) to extraction wells. The lowest hydraulic conductivities are found in the carbonaceous clays of the lower Conquista Clay Unit and the silty to clayey sands of the upper Dilworth Sandstone Member. The most permeable intervals tested are the fossiliferous sands of the middle Conquista Clay Unit and the unconsolidated, fine-to-medium sands of the lower Dilworth Sandstone.

The horizontal hydraulic conductivities in the Deweesville and Conquista Members are highly variable, with a value range of 2 orders of magnitude. The maximum horizontal hydraulic conductivity for the Deweesville/Conquista aquifer is 2.6 ft/d (9.0×10^{-4} cm/s), calculated from aquifer test data from a well screened in the Conquista Sandstone (DOE 1992). Using Darcy's Law, an assumed effective porosity of 0.1, and an average hydraulic gradient of 0.013 to the east-southeast, the maximum average linear groundwater velocity is 130 ft (40 m) per year.

Average linear groundwater velocities in the Dilworth aquifer were calculated using a hydraulic conductivity of 0.68 ft/d (2.4×10^{-4} cm/s) (approximate maximum value from aquifer test), a hydraulic gradient of 0.009 to the east-southeast, and an assumed effective porosity of 0.1 for the fine sands of this zone (DOE 1992). The average linear velocity for groundwater flow in the lower Dilworth aquifer is approximately 22 ft (6.7 m) per year.

A downward hydraulic potential flow exists between the Deweesville/Conquista and Dilworth aquifers. During a 10-hour aquifer test of monitor well 902 completed in the Dilworth, drawdown was observed in an adjacent monitor well (676) screened in the Deweesville. Vertical leakage was calculated to be 7.4×10^{-5} day⁻¹ from the analysis of time-drawdown data. Considering an aquitard thickness of 60 ft (20 m), the vertical hydraulic conductivity is 4.4×10^{-3} ft/d (1.6×10^{-6} cm/s).

4.3.2 Background Groundwater Quality

Background groundwater quality for the Deweesville/Conquista and Dilworth aquifers is defined as the quality of groundwater at the Falls City site that would be present if uranium processing activities had not occurred.

There is no single background groundwater quality for each of these aquifers. The natural groundwater quality varies within these aquifers as a function of residence time and aquifer matrix composition. The Deweesville/Conquista and Dilworth aquifers can each be separated into three general regions or zones with different mineralogical and compositional characteristics. These zones are defined as the oxidized, transitional, and reduced zones. Although these zones overlap, the groundwater in each zone typically is distinct in composition from the groundwater in the other zones. [Table 4-1](#) summarizes the range of background groundwater quality at the site. The constituents and concentrations presented in [Table 4-1](#) are based on the latest available data. Other background water quality data are presented in the Falls City RAP (DOE 1992). The numerous unmined and mined ore bodies in the oxidizing, transitional, and reducing zones of the regional sediments cause considerable variation in the concentrations of hazardous constituents from zone to zone.

4.3.2.1 Deweesville/Conquista

The oxidized zone of the Deweesville/Conquista is defined as the outcrop area and shallow subsurface. At the Falls City UMTRA site, this zone was largely unsaturated before mining and milling. The oxidized zone later became saturated by the influx of large volumes of tailings leachate and mill processing water. Thus, groundwater in this zone at the mill site is not the result of natural processes, and a background groundwater quality for the oxidized, outcrop zone of the Deweesville/Conquista aquifer does not exist in the mill site area.

The transitional zone begins at the downdip edge of the Deweesville/Conquista outcrop (where the sediments are dominantly oxidized) and ends before the downgradient limit of the DOE monitor well array (e.g., 922 and 881, where the sediments are dominantly reduced). Groundwater quality before mining and milling activities in the uranium mineralized zone might have varied from conditions found in monitor well 951 to the much poorer quality groundwater found in monitor well 922. The interaction of oxidizing water from the recharge area with the pyrite- and ore-bearing sediments causes high variability in the background groundwater in the transitional zone.

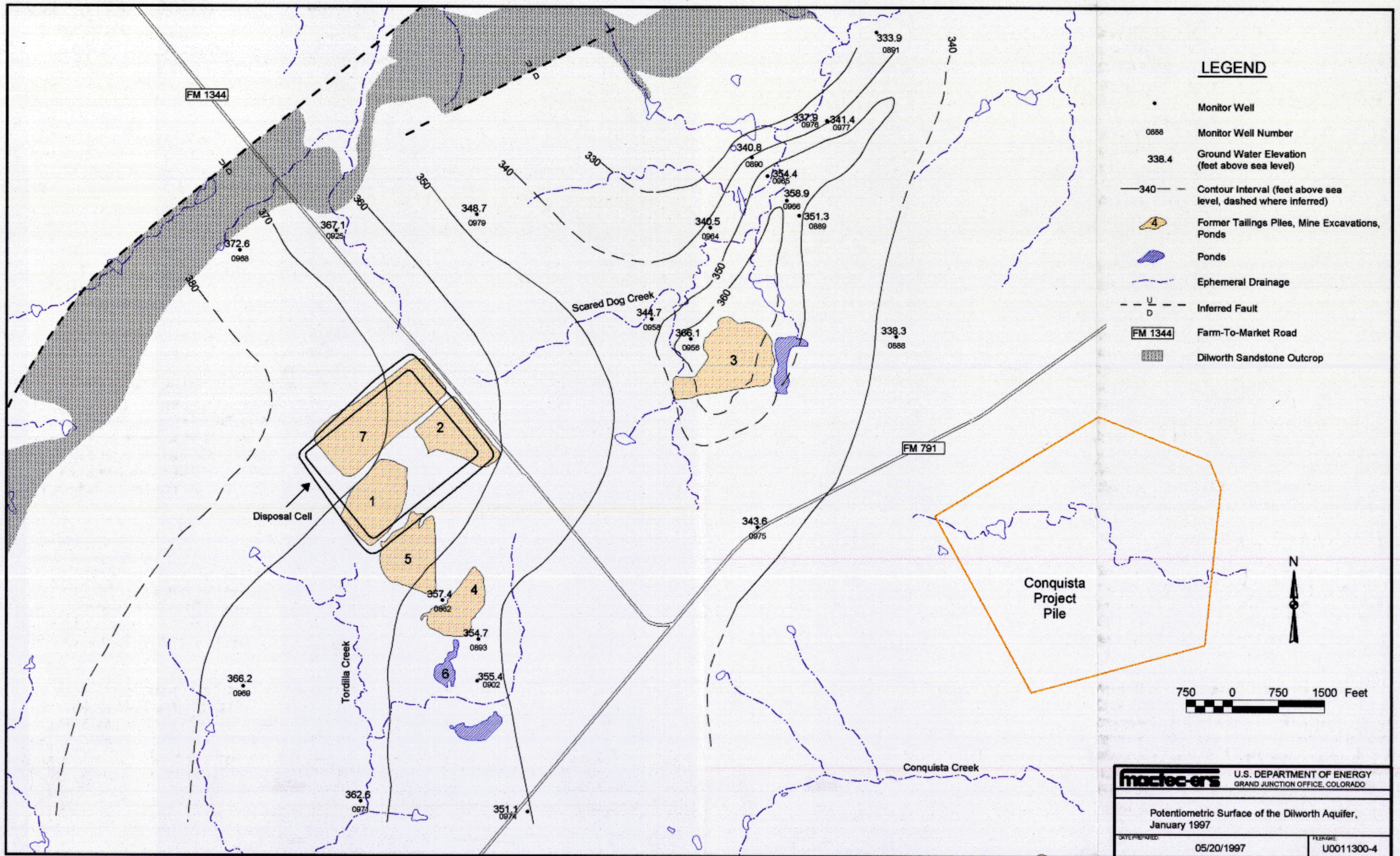


Table 4-1. Typical Water Quality Data for Dilworth and Deweesville/Conquista Background Wells

Constituents	Tailings Fluid	Reduced Zone		Transitional Zone		Oxidized Zone (outcrop area)		
	607	667	668	951	969	967	968	979
Alkalinity		252	250	307	291	116	226	193
Calcium	510	335	405	364	495	278	90	258
Chloride	1040	785	944	708	779	793	338	672
Iron	544	0.45	0.19	0.03	0.87	<0.03	<0.03	<0.03
Magnesium	214	31.8	45.1	29	61	30.5	8.1	28.3
Manganese	22.6	0.21	0.78	0.21	2.94	0.02	<0.01	0.07
Nitrate	<1.0	4.9	3.5	4	1.3	10.2	12.4	4.4
pH	2.93	6.65	6.63	6.75	6.70	5.98	6.58	6.08
Potassium	2.38	43	29	45	43	30	18	36
Sodium	832	678	583	652	550	675	121	531
Sulfate	7390	1043	930	856	1290	817	156	569
Total dissolved solids	11900	3120	3310	2291	3650	2750	624	2210
Uranium	0.908	0.015	0.017	0.008	0.010	0.003	0.068	0.25

Note:

1. Most recent water quality data from same time period, June 1991 and July 1991.
2. Concentrations are reported in milligrams per liter except for pH.
3. Alkalinity reported as mg/L CaCO₃.

The upgradient limit of the reduced zone for the Deweesville/Conquista is defined by the DOE and Texas Bureau of Economic Geology as the downgradient edge of the DOE monitor well array (beginning at FM 791). Groundwater quality data from Conoco monitor wells 667 and 668 suggest the groundwater quality of the Deweesville/Conquista in parts of this zone is lower in sulfate, chloride, and many other constituents than water from the transitional zone. [Figure 4-6](#) shows the locations of the Conoco monitor wells (667 and 668) and Dilworth background monitor wells.

To expand the background water quality data base for the Deweesville/Conquista aquifer, groundwater quality data from other areas in the Deweesville/Conquista were evaluated. Thirty-nine monitor wells were completed in the Deweesville Sandstone before mining activities began at the Hobson *in situ* uranium mine site, 8 or 9 mi (about 13 km) east of the UMTRA site. Of those 39 wells, 28 were completed in the ore body and the remaining 11 were completed nearby. [Table 4-2](#) presents a statistical summary of water quality data obtained from the Deweesville monitor wells.

The Deweesville wells at the Hobson site are generally screened between 300 and 450 ft (90 to 140 m) below land surface. Therefore, groundwater from the Hobson site has probably migrated farther into the reduced zone of this aquifer than groundwater from monitor wells 667 and 668. The greater residence time of contaminants in deeper groundwater is reflected in the lower concentrations of sulfate, chloride, and other major and minor constituents in the Hobson groundwater relative to the 600 series wells ([Table 4-2](#)). Nonetheless, the groundwater from the 600 series wells and the Hobson wells might have followed a similar groundwater quality evolutionary trend. [Figure 4-7](#) shows a trilinear plot of wells 667 and 668 and the 11 Hobson wells drilled around the ore body.

Unlike the major and minor element data, the trace element data from the Hobson area groundwater differ from those of monitor wells 667 and 668. The Hobson data show significantly elevated levels of lead, radium-226, and uranium ([Table 4-2](#)) because most of the Hobson samples were Deweesville groundwater equilibrating with uranium ore.

4.3.2.2 Dilworth

Four upgradient Dilworth monitor wells (967, 968, 969, and 979) are used to delineate the background water quality of this aquifer at the Falls City site. As shown on a trilinear plot ([Figure 4-8](#)), the upgradient Dilworth groundwaters are dominated by no single anionic species, and they contain subequal milliequivalents of sulfate and chloride with lesser bicarbonate. Sodium and calcium are the dominant cations. [Table 4-3](#) presents a statistical summary of the water quality of Dilworth background groundwater.

Of the four DOE Dilworth background wells at the UMTRA site, three (967, 968, and 979) are completed in the oxidized zone, and one (969) is screened in the transitional zone of the aquifer. The groundwater quality of monitor well 969 is more representative of the remaining Dilworth wells at the site. The three upgradient wells in the oxidized zone of the Dilworth aquifer produce groundwater of higher quality than is probably typical of Dilworth groundwater beneath the site.

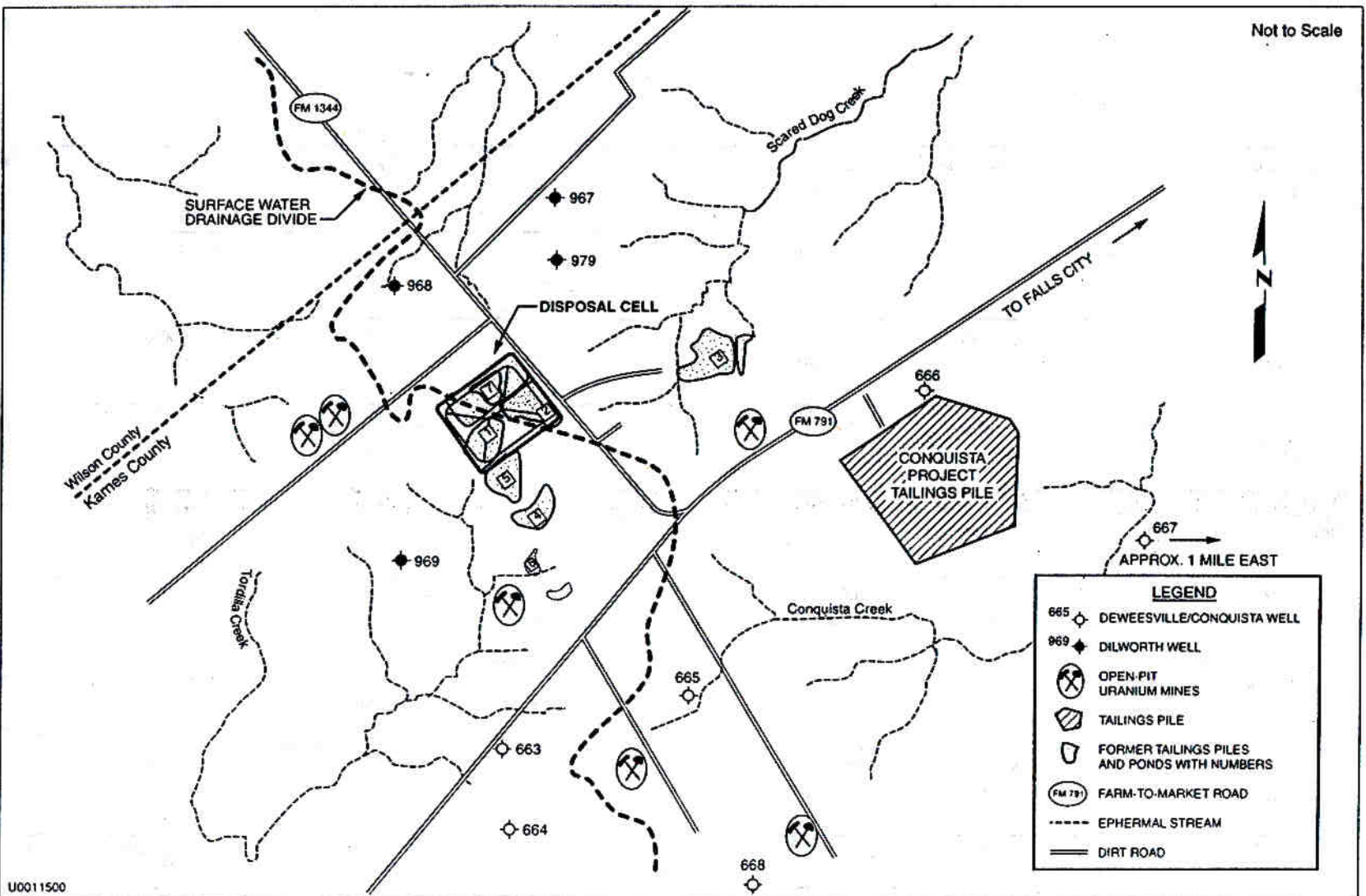


Figure 4-6. Locations of the Dilworth Background Wells and the Deweesville/Conquista Conoco 600 Series Wells, Falls City, Texas, Site

Table 4-2. Water Quality in the Deweesville/Conquista Aquifer at the Falls City, Texas, Site

Constituent	Background Ground Water							
	On-site Crossgradient Well ^b	Area Southeast of FM 791 ^c	Hobson Area ^a		Ground Water at Mill Site by Region			
			Mine Zone	Production Zone	East ^d	North ^e	South ^f	West ^g
Aluminum								
FOD	2/6	0/4	NA	NA	41/44	16/29	27/44	31/36
Range	<0.05-0.05	<0.05-<0.1			<0.05-97.5	<0.014-796	<0.05-109	<0.05-66.2
Ammonia as NH ₄								
FOD	5/6	2/4	NA	NA	27/35	17/23	34/35	28/31
Range	<0.1-0.8	<0.1-0.3			<0.01-3.9	0.0323-268	<0.1-2.1	0.09-2.67
Antimony								
FOD	1/7	0/4	NA	NA	7/33	3/22	3/26	3/23
Range	<0.003-0.014	<0.003-<0.003			<0.003-0.031	<0.001-0.007	0.003-0.008	<0.003-0.013
Arsenic								
FOD	4/7	4/4	?	?	10/37	12/25	17/33	8/31
Range	0.008-0.01	0.01-0.02	0.003-0.035	0.003-0.09	0.001-0.09	<0.005-0.16	0.004-0.39	0.001-0.25
Barium								
FOD	6/7	2/4	?	?	22/33	16/19	24/28	23/27
Range	0.02-0.04	0.03-0.06	<0.4	<0.4	<0.01-0.06	0.01-0.04	0.01-0.05	0.02-0.11
Beryllium								
FOD	0/7	0/4	NA	NA	26/37	10/24	16/31	19/27
Range	<0.005-<0.01	<0.005-<0.01			<0.005-0.62	0.0012-0.38	<0.005-0.2	<0.005-0.09
Boron								
FOD	6/6	4/4	0.06-2.3	0.8-3.0	29/29	18/18	25/25	21/21
Range	0.69-0.96	0.56-1			0.48-2.38	1.11-3.09	0.87-2.37	0.77-2.23
Bromide								
FOD	6/6	4/4	NA	NA	40/42	24/28	38/41	31/32
Range	1-3.9	2.5-4.8			<0.1-11.7	<0.15-18.9	0.8-28.2	0.3-25.4

Table 4-2 (continued). Water Quality in the Deweesville/Conquista Aquifer at the Falls City, Texas, Site

Constituent	Background Ground Water							
	On-site Crossgradient Well ^b	Area Southeast of FM 791 ^c	Hobson Area ^a		Ground Water at Mill Site by Region			
			Mine Zone	Production Zone	East ^d	North ^e	South ^f	West ^g
Cadmium								
FOD	3/7	0/4	?	?	35/42	20/25	21/36	27/34
Range	<0.001-0.009	<0.001-<0.01	0.01-0.01	0.005-0.01	<0.001-0.392	<0.001-0.55	<0.0005-0.22	<0.0005-0.048
Calcium								
FOD	7/7	4/4	?	?	52/52	31/31	48/48	41/41
Range	297-364	330-422	75-180	69-120	323-1060	430-1760	396-2120	540-1720
Chloride								
FOD	7/7	4/4	?	?	50/51	31/31	47/47	41/41
Range	708-780	785-1090	379-600	264-542	<1-2500	1460-4140	704-7480	540-7000
Chromium								
FOD	1/7	0/4	?	?	4/41	7/25	4/36	5/34
Range	<0.01-0.01	<0.01-<0.01	<0.01-0.1	<0.01-0.1	<0.004-0.01	<0.004-0.0351	<0.004-0.02	<0.004-0.07
Cobalt								
FOD	1/7	0/4	NA	NA	38/42	8/24	18/34	24/30
Range	0.01-0.01	<0.03-<0.05			<0.03-1.17	<0.005-0.776	<0.005-0.61	0.0212-0.26
Copper								
FOD	1/7	0/4	?	?	13/33	9/22	13/26	13/23
Range	<0.01-0.03	<0.01-<0.02	0.01-0.2	<0.01-0.5	<0.01-0.25	<0.005-0.12	<0.01-0.07	<0.01-0.11
Fluoride								
FOD	6/6	4/4	?	?	27/32	17/18	25/27	20/24
Range	0.2-0.8	0.6-0.6	0.1-2	0.04-0.4	<0.003-42.5	<0.1-98	<0.1-12	<0.003-4.4
Iron								
FOD	4/7	3/4	?	?	43/52	18/31	43/48	29/41
Range	0.02-0.06	<0.03-0.45	0.06-2.3	0.07-5.8	<0.006-126	0.0237-458	0.02-49.3	<0.03-103
Lead								
FOD	1/7	0/4	?	?	13/41	5/25	7/36	7/34
Range	0.001-0.001	<0.005-<0.01	0.03-0.10	0.02-0.15	0.001-0.04	0.001-0.02	0.001-0.03	0.001-0.02

Table 4-2 (continued). Water Quality in the Deweesville/Conquista Aquifer at the Falls City, Texas, Site

Constituent	Background Ground Water							
	On-site Crossgradient Well ^b	Area Southeast of FM 791 ^c	Hobson Area ^a		Ground Water at Mill Site by Region			
			Mine Zone	Production Zone	East ^d	North ^e	South ^f	West ^g
Magnesium								
FOD	7/7	4/4	?	?	52/52	31/31	48/48	41/41
Range	26.1-32.6	31.8-51	0.3-9.4	1.8-4.2	35.6-574	81-1630	43.5-655	79.1-381
Manganese								
FOD	7/7	4/4	?	?	47/48	30/31	45/45	38/38
Range	0.04-0.55	0.21-0.78	0.1-0.4	0.3-0.3	<0.01-51.4	<0.01-95.1	0.7-50.5	0.34-16.3
Mercury								
FOD	0/6	0/4	?	?	3/41	1/22	1/38	4/30
Range	<0.0002-<0.000	2 <0.0002-<0.0002	<0.001-0.001	<0.001	<0.0002-0.0027	<0.0002-0.0011	<0.0002-0.0002	<0.0002-0.009
Molybdenum								
FOD	3/7	2/4	?	?	9/52	18/31	24/48	10/41
Range	<0.01-0.02	<0.01-0.02	<0.1-0.1	<0.1-0.2	<0.001-0.0219	0.0021-0.09	0.0016-0.68	<0.001-0.25
Nickel								
FOD	2/7	0/4	?	?	36/42	12/25	22/36	28/34
Range	0.01-0.1	<0.04-<0.04	<0.02-0.2	<0.01-0.08	0.03-1.3	0.0212-1.14	<0.007-0.99	0.039-0.29
Nitrate								
FOD	4/7	2/4	?	?	36/43	20/25	32/39	27/36
Range	<0.1-4.4	<1-4.9	1-4	2-9	<0.008-15.4	<0.008-53	<0.008-73.9	<0.008-29.2
Potassium								
FOD	7/7	4/4	?	?	52/52	31/31	48/48	41/41
Range	38-46.4	29-44	31-51	30-45	21.1-96	13-237	36.7-139	39-114
Selenium								
FOD	2/7	0/4	?	?	27/44	18/25	18/39	22/36
Range	0.002-0.012	<0.005-<0.005	0/004-0.05	0.003-0.06	0.00042-0.6	<0.005-0.217	<0.0002-1.2	<0.0002-1.2
Silica								
FOD	6/6	4/4	?	?	33/33	19/19	31/31	29/29
Range	43-49.2	34-58.4	53-76	55-103	11-165	43-171	21.7-141	41.9-198

Table 4-2 (continued). Water Quality in the Deweesville/Conquista Aquifer at the Falls City, Texas, Site

Constituent	Background Ground Water							
	On-site Crossgradient Well ^b	Area Southeast of FM 791 ^c	Hobson Area ^a		Ground Water at Mill Site by Region			
			Mine Zone	Production Zone	East ^d	North ^e	South ^f	West ^g
Silver								
FOD	0/7	0/4	?	?	2/33	1/18	1/26	1/23
Range	<0.01-<0.01	<0.01-<0.01	<0.01-0.02	<0.01-0.09	<0.01-0.08	<0.01-0.07	<0.01-0.01	<0.01-0.01
Sodium								
FOD	7/7	4/4	?	?	52/52	31/31	48/48	41/41
Range	530-652	577-678	313-564	248-399	383-1560	697-4430	606-2280	713-2310
Strontium								
FOD	6/6	4/4	NA	NA	33/33	19/19	32/32	29/29
Range	2.24-2.86	2.4-3			2.51-11.9	6.65-19.6	3-17.9	5.95-27.4
Sulfate								
FOD	7/7	4/4	?	?	51/51	31/31	47/47	41/41
Range	833-910	898-1043	133-345	78-334	1400-5780	1190-16000	1450-3100	1570-2560
Sulfide								
FOD	3/5	2/4	NA	NA	3/27	5/20	3/18	3/18
Range	<0.1-9.2	<0.05-1.4			<0.1-5.4	<0.1-2.6	<0.1-19.2	<0.1-3.1
Thallium								
FOD	0/7	0/4	NA	NA	2/33	3/22	2/26	4/23
Range	<0.01-<0.1	<0.01-<0.01			<0.01-0.1	0.0015-0.4	<0.01-0.08	<0.01-0.1
Tin								
FOD	1/7	0/4	NA	NA	8/33	6/22	2/26	2/23
Range	<0.005-0.06	<0.005-<0.05			<0.005-0.13	<0.001-0.18	<0.005-0.04	<0.005-0.105
Total Cyanide								
FOD	0/5	0/4	NA	NA	1/24	1/15	0/13	2/14
Range	<0.01-<0.02	<0.01-<0.01			<0.01-0.01	<0.01-0.02	<0.01-<0.02	<0.01-0.02

Table 4-2 (continued). Water Quality in the Deweesville/Conquista Aquifer at the Falls City, Texas, Site

Constituent	Background Ground Water							
	On-site Crossgradient Well ^b	Area Southeast of FM 791 ^c	Hobson Area ^a		Ground Water at Mill Site by Region			
			Mine Zone	Production Zone	East ^d	North ^e	South ^f	West ^g
Total Phosphorus as PO ₄								
FOD	5/6	2/4	NA	NA	25/32	16/18	21/29	18/25
Range	0.1-0.3	<0.1-0.1			<0.1-1.1	<0.1-13.6	<0.1-2.4	<0.1-1.6
Uranium								
FOD	7/7	4/4	?	?	49/53	31/31	39/47	39/40
Range	0.008-0.078	0.015-0.0201	0.01-0.06	0.-1-11	<0.001-69.8	0.043-32.9	<0.001-7.96	<0.001-17.9
Vanadium								
FOD	1/7	0/4	?	?	10/37	10/25	4/33	4/31
Range	<0.01-0.04	<0.01-<0.01	<0.2	<0.2	<0.01-0.55	<0.004-3	<0.01-0.05	<0.01-0.09
Zinc								
FOD	6/7	3/4	?	?	38/40	22/25	35/36	32/33
Range	<0.005-0.028	<0.005-0.301	0.12-2.4	0.02-1.2	<0.005-2.64	<0.005-3.1	0.005-2.8	<0.005-1.65
Gross Alpha								
FOD	7/7	4/4			41/41	22/22	35/35	34/34
Range	0-123	0-12.3			0-43000	74.1-17400	-4.25-4200	0-12200
Gross Beta								
FOD	7/7	4/4			41/41	22/22	35/35	34/34
Range	37-81.5	19-64.3			44.5-21500	172-10500	0-2550	0-5500
Lead-210								
FOD	2/2	NA	NA	NA	11/11	8/8	7/7	8/8
Range	0-1.7				0-500.2	0.5-74.5	0.1-57.5	0.5-118
Polonium-210								
FOD	2/2	NA	NA	NA	13/13	9/9	9/9	8/8
Range	0-0.1				0-1.4	0.2-5	0-5.4	0.4-17.5

Table 4-2 (continued). Water Quality in the Deweesville/Conquista Aquifer at the Falls City, Texas, Site

Constituent	Background Ground Water				Ground Water at Mill Site by Region			
	On-site Crossgradient Well ^b	Area Southeast of FM 791 ^c	Hobson Area ^a		East ^d	North ^e	South ^f	West ^g
			Mine Zone	Production Zone				
Radium-226								
FOD	7/7	4/4	?	?	37/37	24/24	32/32	31/31
Range	1.3-2.7	2.1-2.5	0.4-15.5	3.7-1023	0-14.2	1.1-33.5	0.3-140	0.2-654
Thorium-230								
FOD	2/2	NA	NA	NA	13/13	10/10	12/12	12/12
Range	0.1-0.4				0-8.1	0-45.6	0.2-3.6	0.2-53.9

^aNear mine zone—H102, H48, B110, B46, B98, B99, B100, B108, B109, B40, B42, with 11 ground-water samples collected from these wells from 1979 to 1981. Production zone wells—T6-A, M95, M94, M93, T92, M10, M9, M7, M5, M3, T95A, M96, M97, M98, P100, P101, I102, I103, I104, I105, I106, I107, M16, M96, M97, M98, H96, H97; 28 ground-water samples were collected from these wells from 1979 to 1979.

^bMonitor well 951.

^cMonitor wells 667 and 668. Filtered-sample data are from 1991 sampling.

^dWells 940, 953, 955, 963, 965, 966.

^eWells 625, 713, 799, 880, 914, 921.

^fWells 677, 853, 860, 864, 867, 881, 913.

^gWells 854, 859, 882, 904, 918, 919.

NA = Data not available (sample was not analyzed for this constituent).

? = Detection limit not reported.

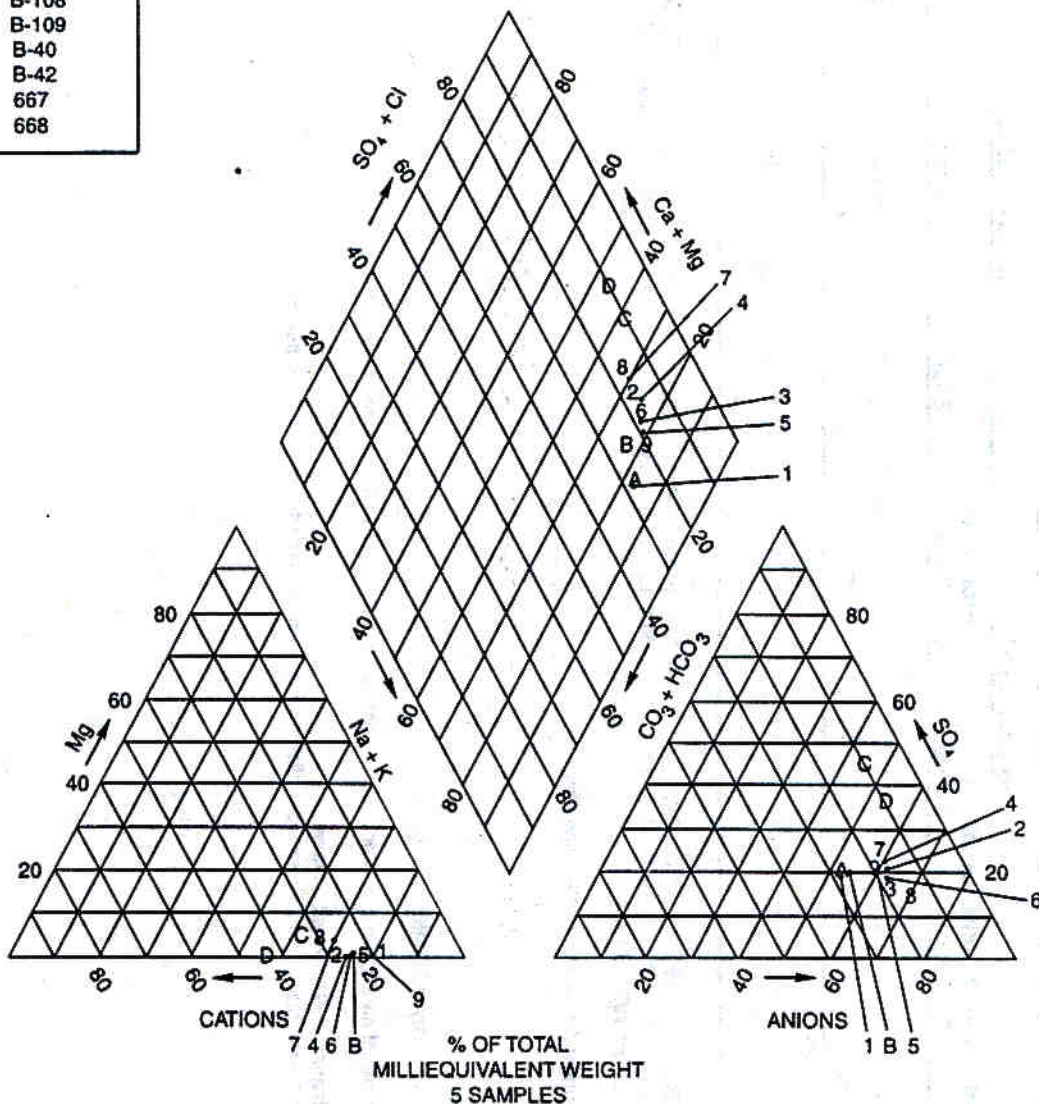
FOD = Frequency of detection; the number of measurements at or above detection limits divided by total number of measurements.

Notes: 1. Filtered samples 1989 to January 1997, except as noted.

2. Concentrations are reported in milligrams per liter, except radionuclides which are reported in picocuries per liter.

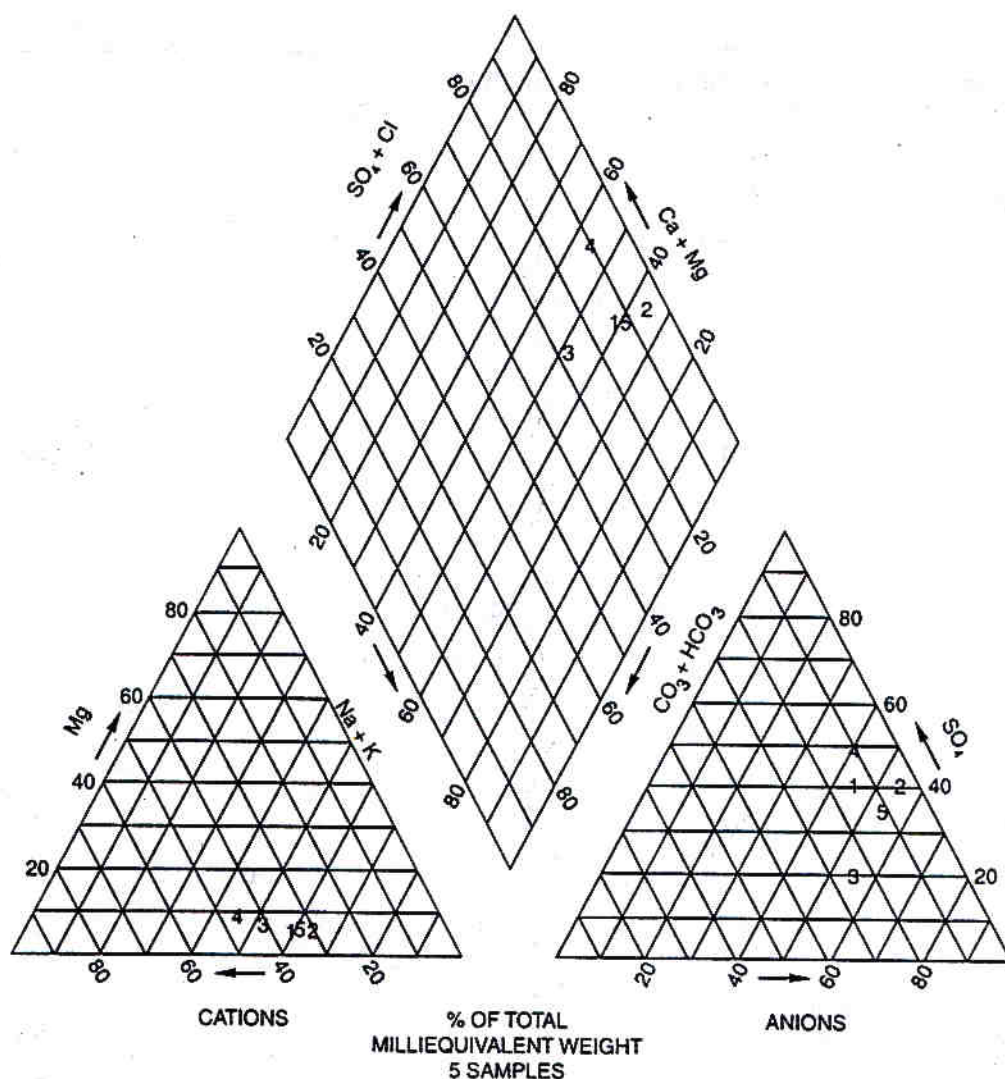
LEGEND

- 1 H-102
- 2 H-4B
- 3 B-110
- 4 B-46
- 5 B-98
- 6 B-99
- 7 B-100
- 8 B-108
- 9 B-109
- A B-40
- B B-42
- C 667
- D 668



U0011600

Figure 4-7. Trilinear Plot of Data from Deweesville/Conquista Monitor Wells 667, 668, and Selected Hobson Monitor Wells, Falls City, Texas, Site



LEGEND

- 1 MW 951 - DEWEESVILLE/CONQUISTA REFERENCE WELL
- 2 MW 967 - DILWORTH BACKGROUND WELL
- 3 MW 968 - DILWORTH BACKGROUND WELL
- 4 MW 969 - DILWORTH BACKGROUND WELL
- 5 MW 979 - DILWORTH BACKGROUND WELL

U0011700

Figure 4-8. Trilinear Plot of Dilworth Background Groundwater and Deweesville/Conquista Reference Water, Falls City, Texas, Site

Table 4–3. Statistical Summary of the Dilworth Groundwater Quality at the Falls City, Texas, Site

Constituent	Frequency of Detection	Observed Concentration		
		Minimum	Median ^a	Maximum
		(mg/L)	(mg/L)	(mg/L)
Aluminum				
Background ^b	2/27	<0.05	^d	0.05
0833 ^c	1/1	0.71	0.71	0.71
0977 ^e	7/7	0.45	0.62	1.2
Ammonia as NH4				
Background ^b	14/24	<0.1	0.1	2
0833 ^c	1/1	5.7	5.7	5.7
0977 ^e	4/5	<0.1	0.13	0.9
Antimony				
Background	2/22	<0.003	^d	0.008
0833	0/1	<0.003	^d	<0.003
0977	1/5	<0.003	^d	0.004
Arsenic				
Background (969)	7/7	0.1	0.22	0.39
0833	1/1	0.05	0.05	0.05
0977	0/5	<0.01	^d	<0.05
Barium				
Background	6/6	0.04	0.05	0.1
0833	1/1	0.03	0.03	0.03
0977	4/5	0.01	0.02	0.02
Beryllium				
Background (969) ^b	0/26	<0.005	^d	<0.01
0833 ^c	0/1	<0.005	^d	<0.005
0977 ^e	1/5	<0.005	^d	0.005
Boron				
Background (967)	4/4	0.88	1.03	1.1
0833	1/1	0.85	0.85	0.85
0977	4/4	0.72	0.825	0.98

Table 4–3 (continued). Statistical Summary of the Dilworth Groundwater Quality at the Falls City, Texas, Site

Constituent	Frequency of Detection	Observed Concentration		
		Minimum	Median ^a	Maximum
		(mg/L)	(mg/L)	(mg/L)
Bromide				
Background (969)	10/10	2.6	3.075	5.8
0833	1/1	1	1	1
0977	7/7	1.7	1.8	2.1
Cadmium				
Background	7/27	<0.001	^d	0.005
0833	0/1	<0.001	^d	<0.001
0977	7/7	0.011	0.017	0.022
Calcium				
Background (969)	11/11	450	489	560
0833	1/1	367	367	367
0977	9/9	188	231	282
Chloride				
Background (967,969) ^b	17/17	680	804	1020
0833 ^c	1/1	472	472	472
0977 ^e	9/9	178	352	553
Chromium				
Background	4/26	<0.01	^d	0.02
0833	0/1	<0.01	^d	<0.01
0977	1/6	<0.004	^d	0.01
Cobalt				
Background	3/27	0.01	^d	0.05
0833	1/1	0.08	0.08	0.08
0977	7/7	0.06	0.07	0.09

Table 4–3 (continued). Statistical Summary of the Dilworth Groundwater Quality at the Falls City, Texas, Site

Constituent	Frequency of Detection	Observed Concentration		
		Minimum	Median ^a	Maximum
		(mg/L)	(mg/L)	(mg/L)
Copper				
Background	4/22	<0.01	^d	0.06
0833	0/1	<0.01	^d	<0.01
0977	2/5	<0.01	^d	0.03
Fluoride				
Background (979) ^b	5/5	0.4	0.4	0.5
0833 ^c	1/1	1	1	1
0977 ^e	1/5	<0.003	^d	0.2
Iron				
Background (969)	11/11	0.24	0.44	2.7
0833	1/1	127	127	127
0977	9/9	0.14	1.1	1.43
Lead				
Background	2/26	0.001	^d	0.002
0833	0/1	<0.005	^d	<0.005
0977	0/6	<0.001	^d	<0.1
Magnesium				
Background (969)	11/11	54	57.8	64.7
0833	1/1	66.5	66.5	66.5
0977	9/9	20	27	32.9
Manganese				
Background (969)	11/11	2.28	2.78	3.7
0833	1/1	3.26	3.26	3.26
0977	8/8	1.37	1.69	2.37

Table 4–3 (continued). Statistical Summary of the Dilworth Groundwater Quality at the Falls City, Texas, Site

Constituent	Frequency of Detection	Observed Concentration		
		Minimum	Median ^a	Maximum
		(mg/L)	(mg/L)	(mg/L)
Mercury				
Background ^b	0/30	<0.0002	^d	<0.0002
0833 ^c	0/1	<0.0002	^d	<0.0002
0977 ^e	2/7	<0.0002	^d	0.0005
Molybdenum				
Background (968,969)	12/17	<0.01	0.03	0.07
0833	1/1	0.02	0.02	0.02
0977	1/9	<0.001	^d	0.01
Nickel				
Background	2/27	0.01	^d	0.01
0833	1/1	0.09	0.09	0.09
0977	7/7	0.07	0.09	0.11
Nitrate				
Background	21/28	<1	3	12.8
0833	1/1	1.8	1.8	1.8
0977	5/7	<0.008	1.8	6.4
Potassium				
Background (969) ^b	11/11	37	40	43.9
0833 ^c	1/1	44	44	44
0977 ^e	9/9	24	31.3	60.9
Selenium				
Background	9/27	0.002	^d	0.024
0833	0/1	<0.005	^d	<0.005
0977	1/7	<0.0002	^d	0.007

Table 4–3 (continued). Statistical Summary of the Dilworth Groundwater Quality at the Falls City, Texas, Site

Constituent	Frequency of Detection	Observed Concentration		
		Minimum	Median ^a	Maximum
		(mg/L)	(mg/L)	(mg/L)
Silica				
Background (968)	5/5	88	89.4	99.7
0833	1/1	44.5	44.5	44.5
0977	4/4	88	101.85	121
Silver				
Background	1/22	<0.01	^d	0.02
0833	0/1	<0.01	^d	<0.01
0977	0/5	<0.01	^d	<0.01
Sodium				
Background (967, 969)	17/17	482	541	675
0833	1/1	604	604	604
0977	9/9	412	484	520
Strontium				
Background (979) ^b	6/6	1.51	1.77	76.8
0833 ^c	1/1	3.27	3.27	3.27
0977e	4/4	1.65	2.32	2.62
Sulfate				
Background (969)	11/11	1080	1290	1440
0833	1/1	1930	1930	1930
0977	9/9	1160	1310	1580
Sulfide				
Background	6/24	<0.1	^d	55
0977	0/5	<0.1	^d	<1
Thallium				
Background	1/22	<0.01	^d	0.1
0833	0/1	<0.05	^d	<0.05
0977	0/5	<0.01	^d	<0.1

Table 4–3 (continued). Statistical Summary of the Dilworth Groundwater Quality at the Falls City, Texas, Site

Constituent	Frequency of Detection	Observed Concentration		
		Minimum	Median ^a	Maximum
		(mg/L)	(mg/L)	(mg/L)
Tin				
Background	5/22	<0.005	d	0.019
0833	0/1	<0.1	d	<0.1
0977	2/5	0.01	d	0.02
Total Cyanide				
Background	2/20	<0.01	d	0.02
0977	1/5	<0.01	d	0.01
Total Phosphorus as PO4				
Background	19/22	<0.1	0.5	1.6
0833	1/1	0.5	0.5	0.5
0977	3/4	<0.1	0.15	0.2
Uranium				
Background (968) ^b	6/6	0.026	0.06025	0.094
0833 ^c	1/1	3.04	3.04	3.04
0977e	9/9	0.016	0.025	0.054
Vanadium				
Background	11/26	<0.01	d	0.05
0833	0/1	<0.01	d	<0.01
0977	1/5	<0.01	d	0.03
Zinc				
Background	19/27	<0.005	0.016	0.544
0833	1/1	0.213	0.213	0.213
0977	6/6	0.12	0.171	0.206
Gross Alpha				
Background	26/26	0	15.65	183
0833	1/1	1400	1400	1400
0977	6/6	0	27.45	76.2

Table 4–3 (continued). Statistical Summary of the Dilworth Groundwater Quality at the Falls City, Texas, Site

Constituent	Frequency of Detection	Observed Concentration		
		Minimum	Median ^a	Maximum
		(mg/L)	(mg/L)	(mg/L)
Gross Beta				
Background	26/26	12.7	38.75	340
0833	1/1	650	650	650
0977	6/6	28.78	55.35	169
Lead-210				
Background ^b	10/10	0	1.45	6.8
0833 ^c	d	d	d	d
0977 ^e	2/2	0	0.4	0.8
Polonium-210				
Background	12/12	0	0.25	2.6
0833 ^c	d	d	d	d
0977	2/2	0	0.05	0.1
Radium-226				
Background (969)	7/7	2	2.8	4.6
0833	1/1	d	2.4	d
0977	5/5	0.7	1.2	1.9
Thorium-230				
Background	12/12	0.1	0.35	0.9
0833	d	d	d	d
0977	2/2	0.1	0.3	0.5

^aThe median, or 50th percentile of the sample data, cannot be determined if 50 percent or less of the data are above detection.^bData are pooled from monitor wells 967, 968, 969, and 979 unless one or more of these wells has significantly higher levels than the others. In such cases, background represents the higher levels. Well numbers are indicated in parenthesis.^cRepresents the western contaminated zone. Water quality data from one sampling round in December 1991 were used to determine constituents of concern for this contaminated zone.^dData not available^eRepresents the eastern contaminated zone. Water quality data from 1989 through 1997.

Note: Filtered Samples are 1989 through 1997.

4.3.3 Magnitude of Site-Related Groundwater Contamination

A statistical, geochemical, and hydrological analysis of the Falls City water quality data for 1989 through 1997 indicates tailings-related contamination in the Deweesville/Conquista aquifer, with less contamination in the Dilworth aquifer. The extent of contamination in the aquifers can be inferred by using pH measurement results to discriminate tailings related contaminated groundwater from background waters. Previous geochemical characterization of tailings related contaminants by the Bureau of Economic Geology (BEG 1992) demonstrated that the dissolution of aluminosilicates present in the ore matrix (clay and shale) by sulfuric acid solutions used in the acid leaching process buffer the pH of the tailings solutions to about 3 or 4. Dissolution of the ore matrix is also the source of elevated levels of aluminum, arsenic, cadmium, manganese, molybdenum, selenium, and uranium observed in many of the groundwater samples collected at the Falls City site. Thus, low pH values are a useful geochemical parameter indicative of tailings related contamination.

A bimodal distribution of pH values at the Falls City site (Figure 4-9) can be seen by examining the frequency diagram of pH measurements from groundwater and tailing solutions (BEG 1992). The frequency diagram shows an absence of waters with pH values between 4.75 and 5.0 indicating the presence of two different pH buffers. The dominant source of acidity in the contaminated groundwater is the aluminum-sulfate pH buffer illustrated by the distribution of relatively low pH values ranging from 2.75 to 4.5. Bicarbonate is the high pH buffer reflecting background water quality with values ranging from 5.25 to 7.0. Therefore, groundwater having a pH less than 4.75 to 5.0 is considered an indicator of tailings related contamination.

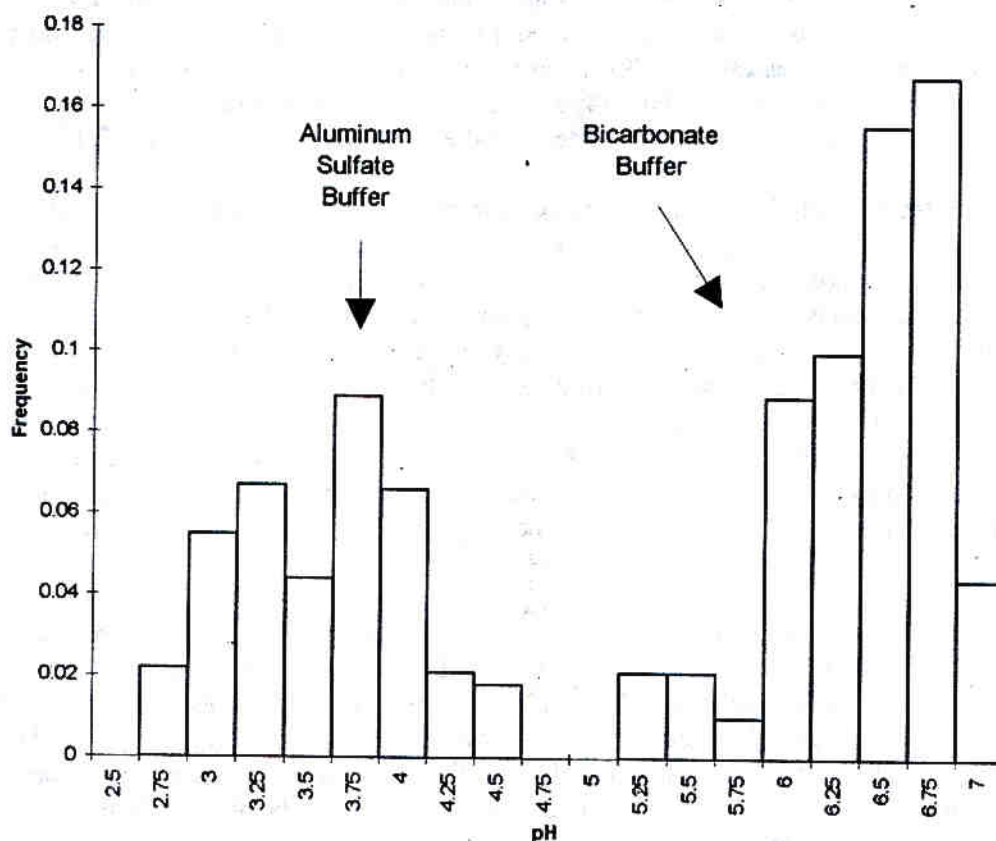


Figure 4-9. Bimodal Distribution of pH Values from BEG 1992

4.3.3.1 Deweesville/Conquista Contaminant Plume

Tailings related contaminants in the Deweesville/Conquista aquifer can be inferred by the distribution of the low pH values delineated in [Figure 4–10](#). In general, contamination at the Falls City site occurs in two distinct zones; an eastern contaminant zone and a western contaminant zone. The eastern zone is associated with the former tailings pile 3 and the western zone is associated with former tailings piles 1, 2, 4, 5, 6, and 7. Although both contaminated zones contain many chemical similarities, each zone has important chemical differences that give it a distinct geochemical signature.

Eastern Contaminant Zone

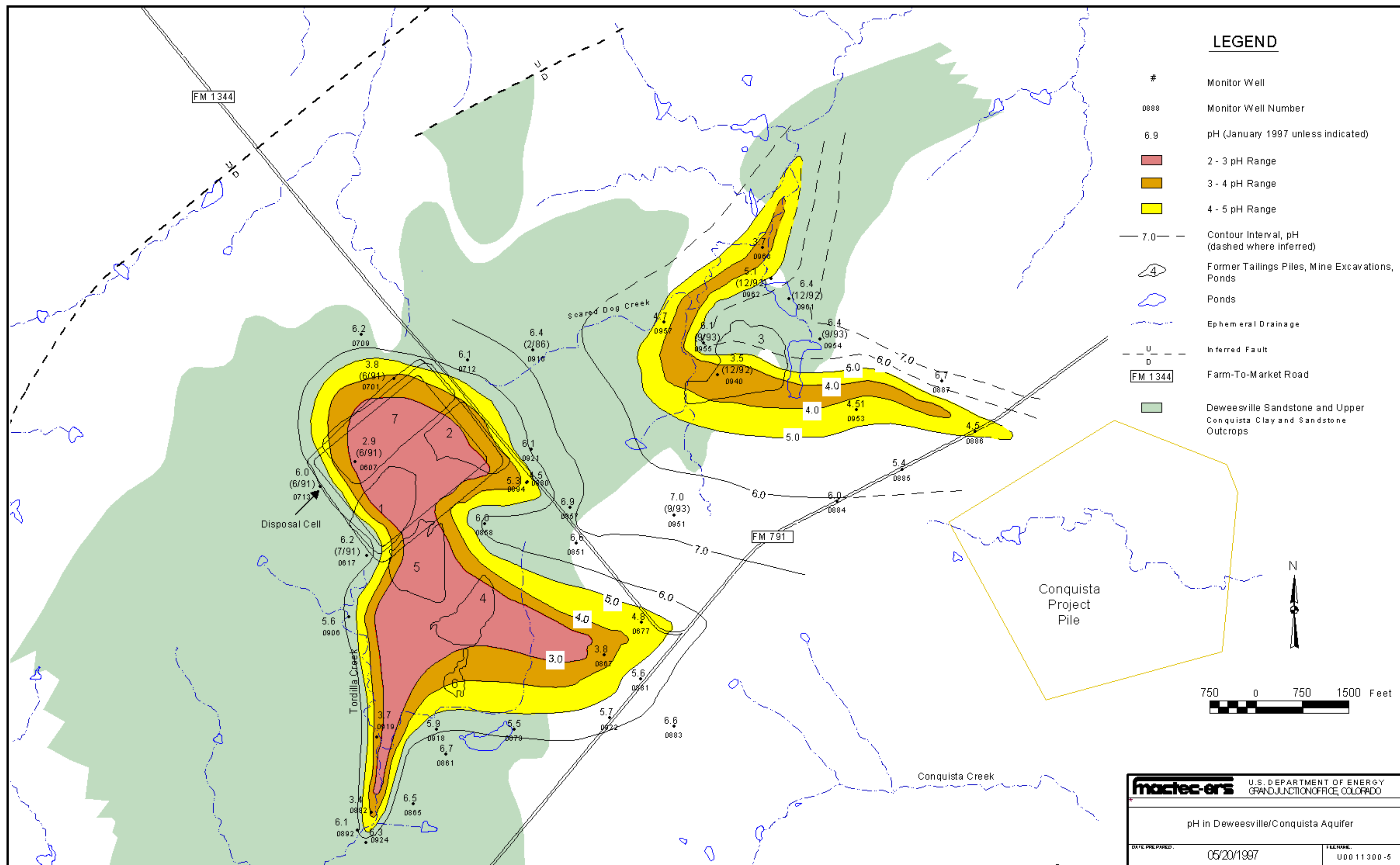
The eastern contaminant zone originates from tailings pile 3. Groundwater with relatively low pH values, indicative of tailings related contamination, extends from former tailings pile 3 in two directions; north beneath Scared Dog Creek and east beneath FM 791.

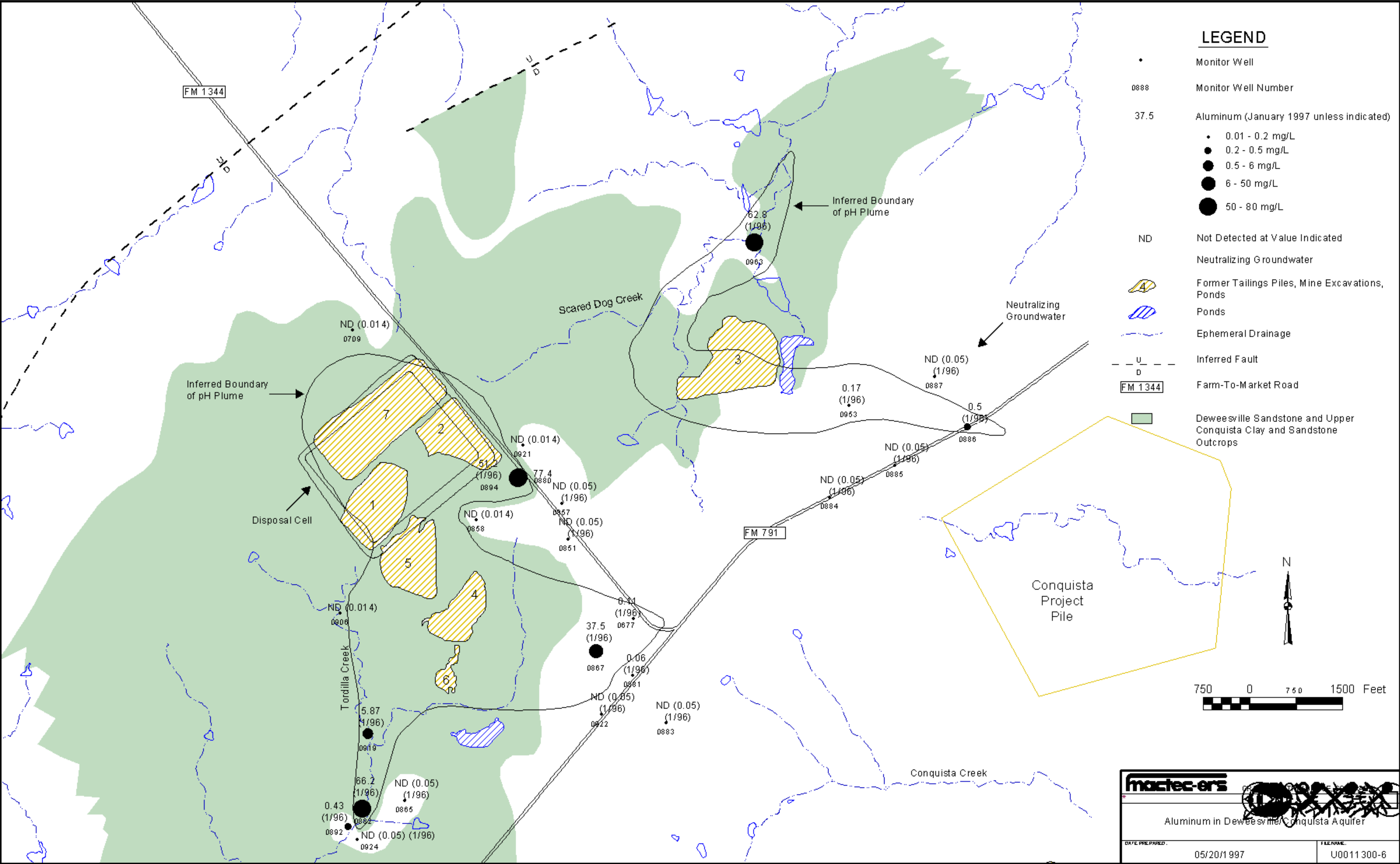
Contaminated groundwater appears to extend approximately 3,000 ft (900 m) to the north along the direction of Scared Dog Creek. The leading edge of the contaminant plume migrating beneath Scared Dog Creek can be inferred by the relatively low pH value of 3.7 observed in water sampled from monitor well 963, the most downgradient sample location. The width of the pH plume in this area is relatively narrow (approximately 750 ft), as evidenced by an increase in pH to 4.7, 6.1, and 5.1 at monitor wells 957, 955, and 962, respectively.

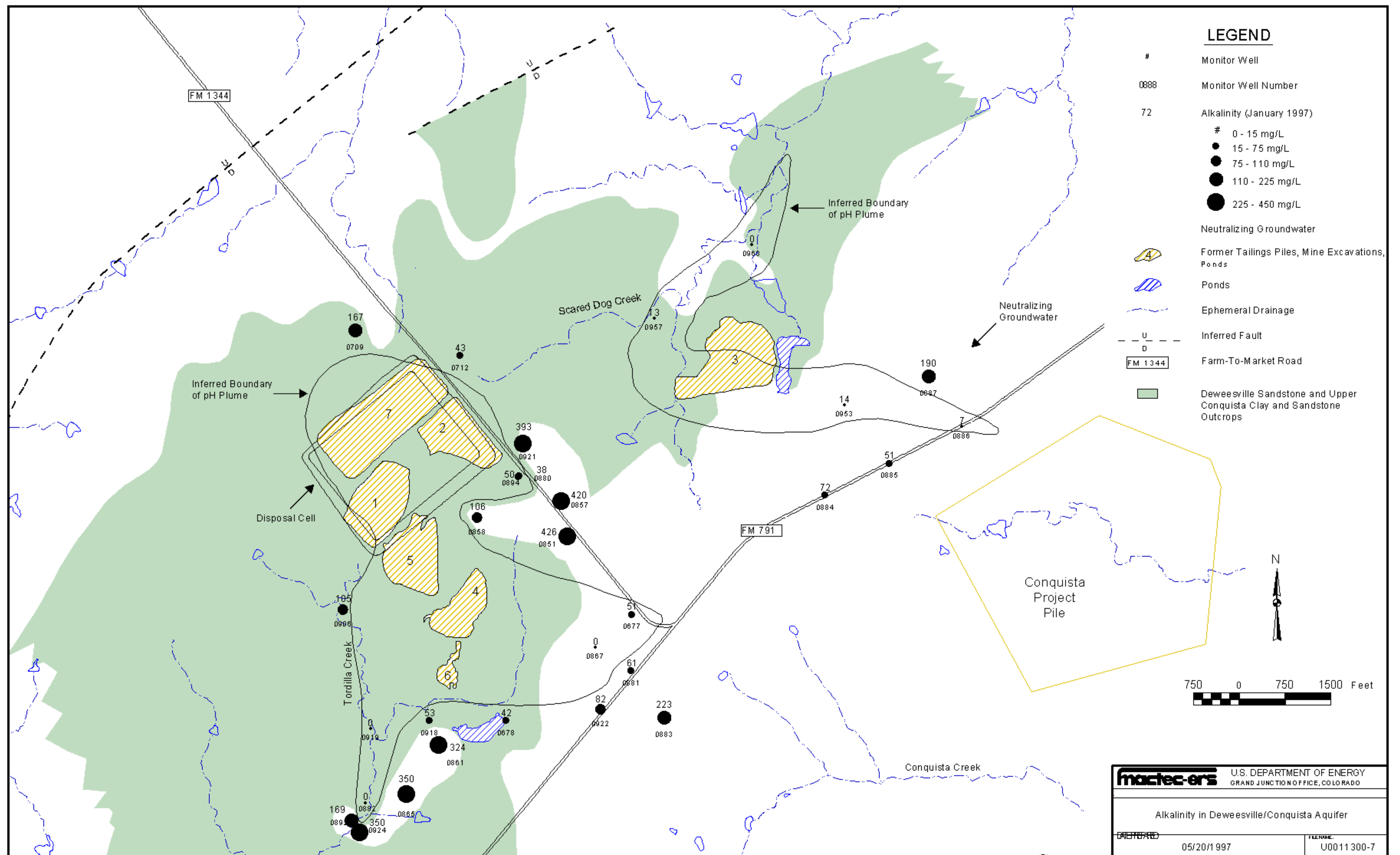
The extent that the contaminant plume has migrated east of former pile 3 can be inferred by examination of groundwater samples collected in January 1997 from several new monitor wells installed in 1995 near FM 791. A pH value of 4.5 measured in water collected from monitor well 886 indicates the leading edge of the plume has migrated beneath FM 791, approximately 3,500 ft (1,100 m) east of former pile 3. The width of the plume is approximately 600 ft (450 m), as inferred by an increase in pH values to 5.4 and 6.7 observed in water samples collected from downgradient monitor wells 885 and 887, respectively.

Aluminum, and to a lesser extent iron, comprise the predominant sulfate salts in tailings solutions which control the acidity of the pH plumes at the Falls City site (BEG 1992). Geochemical reactions with common aluminum silicates (e.g., potassium feldspars) as the pH plume migrates through the Conquista sandstone, clay, and shale units will not neutralize the plume because the waters are already near equilibrium with the aluminosilicates due to the relatively high concentrations of aluminum, silica, and alkalies. However, the pH plume may be neutralized naturally by reacting with calcite or bicarbonate (alkaline) groundwaters. Only a small amount of calcite (0.06 volume percent) present in the Deweesville/Conquista sediments or mixing approximately 8 percent of the plume with 92 percent alkaline groundwaters is required to neutralize the plume. The lower the aluminum and iron content of the groundwater, regardless of pH, the greater the probability that reaction with calcite or mixing with alkaline waters will neutralize the pH plume.

Aluminum concentrations and alkalinity measured in groundwater samples from the most recent sampling rounds (1996 and 1997) are presented in [Figures 4–11](#) and [4–12](#), respectively. Relatively low aluminum concentrations and relatively high alkalinity values are observed in water samples collected from monitor wells 884, 885, and 887 which are located near the lateral edges of the pH plume that has migrated beneath FM 791. Results for monitor well 886 located near the leading edge of the plume is only slightly elevated in aluminum (0.5 mg/L), suggesting that aluminum contamination related to the tailings is precipitating, thereby lowering the aluminum concentrations and increasing the pH in the plume due to reactions with alkaline groundwater. Since the pH (4.5) at this location is at the upper range







of pH for the aluminum-sulfate buffer (Figure 4–9), and the aluminum concentrations are relatively low, additional mixing with the down gradient alkaline groundwater will raise the pH into the bicarbonate buffer range. Thus, further down gradient migration of the pH plume beneath FM 791 is limited.

Western Contaminant Zone

The western contaminant zone is associated with former tailings piles 1, 2, 4, 5, 6, and 7. Relatively low pH groundwater extends radially away from former tailings piles 2 and 7 (Figure 4–10). The radial shape of the pH plume in this area is consistent with a groundwater mound as are the potentiometric groundwater surface contours shown in Figure 4–4.

Locally in this zone, sulfate levels in the groundwater are high; 16,000 and 15,300 mg/L in monitor wells 880 and 894, respectively. The high sulfate concentrations in this part of the Deweesville/Conquista aquifer are probably associated with a tailings pond that existed in the southern end of former pile 2. Sulfate contamination decreases significantly within a short distance away from the former pile. For example, sulfate concentrations decrease to 1,460 mg/L in water from monitor well 921, located approximately 500 ft north of monitor wells 880 and 894. Concentrations decrease to 1,680 mg/L sulfate at monitor well 858 and to 232 mg/L sulfate at monitor well 857, located approximately 1,000 ft south and southeast, respectively, of former pile 2.

Contaminated groundwater from tailings piles 4 and 5 appears to extend in two directions; southeast approximately 2,500 ft (760 m) to FM 791 and south more than 3,000 ft (900 m) beneath Tordilla Creek. Both contaminant plumes are characterized by low pH waters (Figure 4–10). Further migration of the pH plume appears to be limited by loss of the aluminum-sulfate pH buffering capacity due to the presence of low aluminum concentrations (Figure 4–11) and the bicarbonate levels (Figure 4–12) in background water quality downgradient from the plume.

The area between former piles 4 and 5 contains a 1- to 3-ft (0.3- to 1-m)-thick zone of acid-, sulfate-, and possibly metals-rich groundwater perched on top of a thin but laterally extensive silicified layer in the Deweesville/Conquista. The shallow perched saturated zone was probably generated by horizontal flow along this silicified layer when tailings leachate was injected into piles 4 and 5 during *in situ* mining operations (DOE 1992).

4.3.3.2 Dilworth Contaminant Plume

Tailings related contaminants associated with the former tailings pile 3 are present in the Dilworth aquifer as evidenced by the distribution of the low pH values delineated in Figure 4–13. The pH plume map presented in Figure 4–13 reveals that contaminated groundwater has migrated at least 2,000 feet (1,200 m) north of former pile 3 where relatively low pH (3.7) water is present at monitor well 965. Contamination does not appear to be present at the most down gradient monitor well 891, located approximately one mile north of the former pile 3. The pH value (5.7) in the groundwater at this down gradient location (well 891) is consistent and within the pH range expected for the bicarbonate buffer system (background water quality) shown in Figure 4–9. Moderate levels of alkalinity (76 mg/L as CaCO_3) and non-detectable levels of aluminum (<0.05 mg/L) at this location provide additional evidence that contamination has not migrated down gradient to monitoring well 891.

The width of the contaminant plume is approximately 1,000 feet (300 m) wide as inferred by the sampling results for monitor wells 889, 890, 965 and 966. Monitor wells 889 and 890 were installed in 1995 to provide additional control to characterize the plume.

Contamination in the Dilworth aquifer was previously identified in groundwater samples collected from monitor well 833 situated near the southern end of the former tailings pile 4 (DOE 1995). However, only two samples (February 1986 and December 1991) were collected from the well before it was abandoned during construction of the disposal cell. Results of the 1986 and 1991 groundwater analyses for selected analytes are presented in [Table 4-4](#).

Results for monitor well 833 indicate a decrease in pH and a significant increase in ammonium, iron, manganese, sulfate, and uranium concentrations between 1986 and 1991 (DOE, 1992b), suggesting the Dilworth may be contaminated in this area. For this reason, monitor well 893 was installed in 1995 adjacent to the former location of monitor well 833, to evaluate the potential of contamination in the Dilworth aquifer (Figure 4-3).

The new monitor well 893 was sampled in 1996. Results are presented in Table 4-4. Examination of the results presented in Table 4-4 do not indicate contamination in the Dilworth by the former processing site activities, suggesting the samples collected from well 833 may have been cross contaminated from the Deweesville/Conquista aquifer as a result of an improper well completion.

Table 4-4. Comparison of Groundwater Results Obtained for Monitor Wells 833 and 893

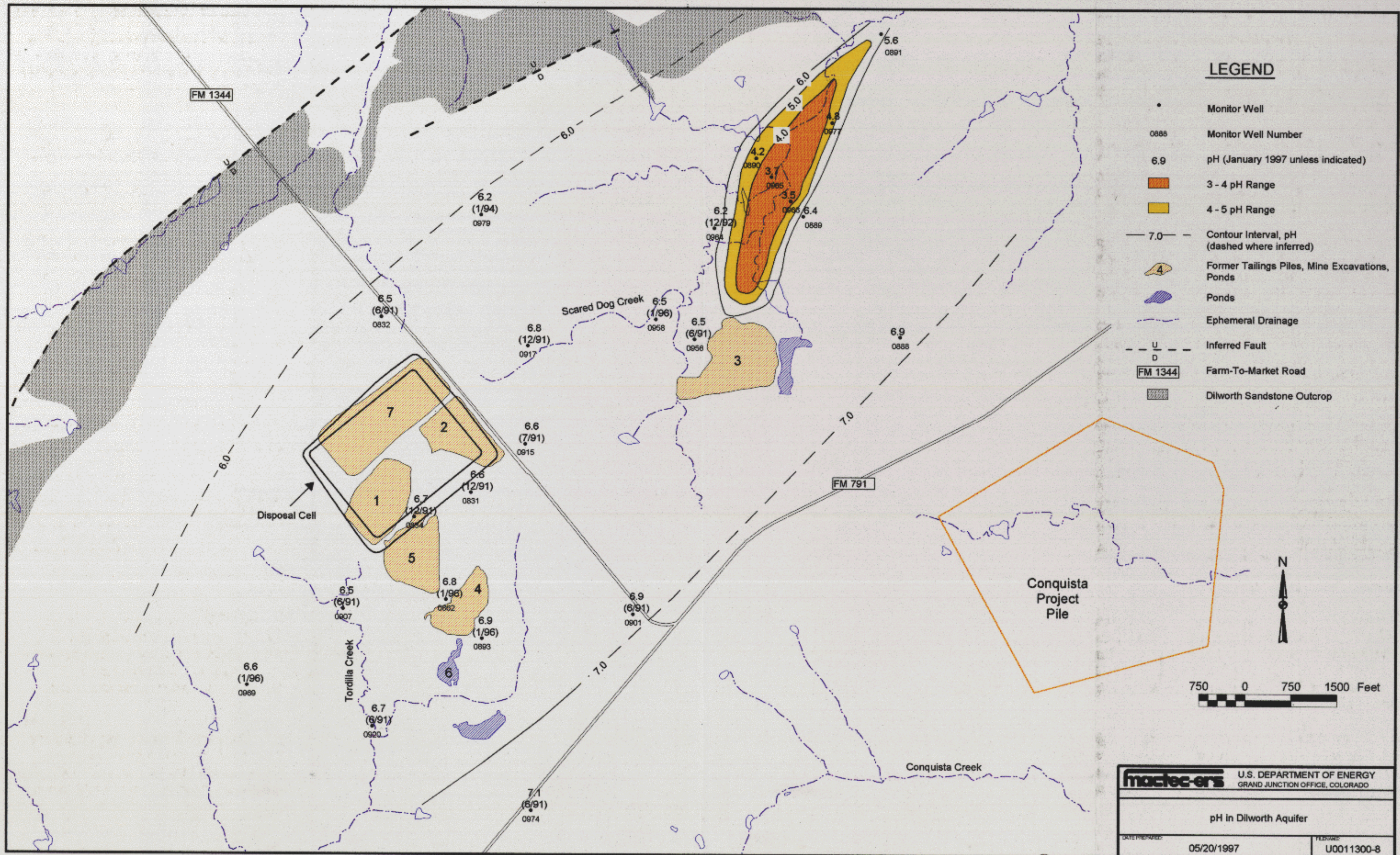
Parameter	Monitor Well 833		Monitor Well 893
	1986	1991	1996
pH	6.7	5.8	6.9
ammonium (mg/L)	0.6	5.7	0.4
iron (mg/L)	35.3	127	0.12
manganese (mg/L)	1.5	3.3	0.3
sulfate (mg/L)	1,170	1,930	749
uranium (mg/L)	0.6	3.0	ND (0.001) ^a

^aND = value is less than indicated detection limit

4.3.4 Contaminant Fate and Transport

The chemical species present in aqueous systems are a function of pH, Eh, and the concentrations of different anions and cations. Speciation determines the mobility of the chemicals and might also influence their toxicity. The predominant species of the contaminants of concern for human health were predicted through the geochemical model MINTEQA2 (Allison et al. 1991). The contaminants of concern are identified in the site-specific baseline risk assessment (in preparation): cadmium, cobalt, fluoride, nickel, iron, sulfate, and uranium.

Constituents in the contaminated zone waters are subject to dilution and to different chemical reactions including oxidation/reduction, precipitation and coprecipitation, possible reactions with biologic organisms, and adsorption onto aquifer mineral surfaces. Concentrations of the dominantly cationic metals and the major cations calcium, magnesium, potassium, and sodium are controlled by dilution and



precipitation and sorption reactions. Cadmium, iron, cobalt, nickel, and fluoride concentrations will also be controlled by these processes. Chloride concentrations are affected only by dilution or evaporation. Attenuation mechanisms that should control the concentrations of the contaminants of concern for the Falls City site are discussed below.

Cadmium

Cadmium will be removed rapidly by the precipitation of otavite (CdCO_3) and by hydrolysis reactions as the low pH of the tailings leachate is neutralized by alkaline groundwater and the calcite in the aquifer matrix. Dilution with background water produces cadmium concentrations below detection limits in downgradient groundwater. Elevated cadmium levels are restricted to the areas underneath or immediately adjacent to the tailings pile.

Iron, Cobalt, and Nickel

Aqueous species of iron are typically not stable in groundwater that is oxidizing and that has a pH near or above 6. Dissolved iron in oxidizing water with a pH of 7 should oxidize rapidly and remove as iron oxyhydroxides. Although groundwater from many downgradient monitor wells in the Deweesville/Conquista yields pH measurements below 4 and has iron levels significantly higher than reference well 951, groundwater from only one Dilworth well (977) has an acidic pH. The pH in groundwater from Dilworth background well 969 is historically between 6.5 and 7 (DOE 1992). Nonetheless, iron concentrations in these waters are well above the values present in the other Dilworth background wells at the site.

Elevated cobalt levels might have been introduced to the aquifer by acidic tailings leachate. Because of its chemical similarity to iron, however, cobalt typically coprecipitates during the precipitation of manganese and iron hydroxides. At the typical pH range (6 to 8) observed for groundwater in the Dilworth aquifer at the Falls City site, cobalt should be present at levels below or near the detection limit. Slightly elevated cobalt levels (e.g., up to 0.05 mg/L in monitor well 969) and iron levels could be expected in naturally reducing, alkaline, background Dilworth groundwaters. More elevated cobalt concentrations can occur in low-pH contaminated groundwater (up to 0.09 mg/L in acidic Dilworth monitor well 977). When the pH of this oxidizing water rises above 5.5, cobalt concentrations should be much lower.

Sulfate

Sulfate concentrations in the contaminated zones of the aquifer immediately adjacent to the processing site are controlled primarily by gypsum solubility. Farther downgradient, sulfate concentrations are controlled largely by physical processes such as dispersion and dilution. Reduction of sulfate to sulfide is also possible if the contaminated zone interacts with reducing sediment or groundwater. Presently, gypsum precipitation predominantly controls sulfate concentrations because the shallow groundwater in and around the tailings piles was saturated with gypsum. As the tailings piles are consolidated and covered, the sulfate level in groundwater around the former piles will decrease. Eventually, as sulfate levels drop below gypsum saturation, the gypsum that precipitated previously will begin to redissolve. The dissolution of gypsum will buffer the sulfate concentrations at fairly high levels until the gypsum supply is exhausted. At this point, natural flushing with background water will substantially lower the sulfate concentrations in the former tailings pile area.

Because the sulfate concentrations are high, adsorption reactions probably will not significantly affect sulfate concentrations in the shallow groundwater. Given the high redox potential of the shallow groundwater in the Deweesville/Conquista and Dilworth aquifers, sulfate removal by reduction to sulfide is not likely until the contamination migrates well off the site.

Uranium

Uranium is mobile in acidic groundwater (e.g., pH is 3 to 4) where it typically exists as positively charged uranyl, uranium hydroxyl, and (in high sulfate systems) uranium sulfate complexes. In oxidizing, alkaline groundwater over a range of elevated pH values (e.g., between 6.5 and 8.5), uranium can form stable anionic carbonate complexes that facilitate uranium transport in groundwater.

Uranium levels are elevated in both acidic and alkaline groundwater at the Falls City site. In both these environments, uranium concentrations will be reduced mainly by adsorption onto aquifer materials and by dilution with uncontaminated groundwater.

4.3.5 Risk Evaluation

The uranium milling activities at the Falls City site led to groundwater contamination in the Deweesville/Conquista and Dilworth aquifers. The near-surface geologic members include the Deweesville, the Conquista, and the Dilworth. For assessing risk to potential groundwater users, the Deweesville and Conquista water-bearing members are evaluated as a single aquifer.

Residents near the site use groundwater from the deeper Carrizo aquifer (2,000 to 3,000 ft [600 to 900 m] below the surface). Because of its depth below the land surface and the confining layer overlying the aquifer, the Carrizo aquifer is not affected by mining and milling activities at the Falls City site.

4.3.5.1 Dilworth Aquifer

Groundwater from the Dilworth aquifer was historically considered to be poor quality. No drinking-water wells are screened in the Dilworth aquifer within a 2-mi (3-km) radius of the site (DOE 1995). This is because historically the Dilworth groundwater was considered to be of poor quality. Although the DOE does not have evidence of its use, groundwater from the Dilworth aquifer might have been used for watering livestock in the vicinity of the site. Using these livestock for food could create an exposure pathway to humans. Therefore, the potential current and future use of the Dilworth aquifer at the site was evaluated.

Levels of aluminum, ammonium, cadmium, cobalt, fluoride, iron, nickel, sulfate, uranium, and zinc in groundwater from two monitor wells completed in the Dilworth aquifer were significantly higher (at the 0.10 level of significance) than the concentrations reported in groundwater from background wells (DOE 1994). As discussed in Section 4.3.3.2, groundwater contamination in monitor well 833 (Figure 4–3) may have been due to vertical leakage through the monitor well's annulus. Groundwater contamination in monitor well 977 (Figure 4–3) is derived from the zone of contamination along Scared Dog Creek that intercepts the Dilworth outcrop. Therefore, the contamination in the Dilworth appears to be confined to a few isolated areas. The constituents elevated above background are presented in [Table 4–5](#).

Table 4–5. Contaminants of Potential Concern for the Dilworth Aquifer

Contaminant levels exceed background	Contaminant levels in nutritional range	Contaminants of low toxic potency and/or high dietary range	Contaminants of potential concern^a
Aluminum Ammonium Cadmium Cobalt Fluoride Iron Nickel Sulfate Uranium Zinc	Zinc	Aluminum Ammonium	Cadmium Cobalt Fluoride Iron Nickel Sulfate Uranium

^aScreening process has started with the first column; constituents listed in the second and third columns were subtracted from the list of constituents in the first column; the remaining constituents form the list shown in the last column.

High levels of arsenic and manganese occur naturally in some areas of the Dilworth aquifer. Both arsenic and manganese typically are associated with the uranium ore deposits found in the Falls City site area. Also, high levels of sulfate occur naturally in the Dilworth groundwater and are associated with gypsum deposits.

Although zinc was observed above background, it was eliminated as a contaminant of potential concern because it is an essential nutrient and because the levels at which it is observed are within nutritional ranges, even when added to expected dietary intake. Ammonium and aluminum were eliminated as contaminants of potential concern based on low toxicity, and because the levels at which they are observed in the most contaminated downgradient monitor wells will not produce adverse health effects. Cadmium, cobalt, fluoride, iron, nickel, sulfate, and uranium remain as the contaminants of potential concern for the Dilworth.

Potential adverse health effects are a function of the contaminant amount an individual takes into his or her body. The risk of exposure to humans was estimated by examining the three ways in which contaminants can enter the body: drinking the water, eating meat from livestock which drank the water, or drinking milk from livestock which drank the water.

It should be kept in mind that the highest contaminant concentrations from the most contaminated wells were used to estimate the amount of exposure. Therefore, this evaluation provides the upper limit of possible risks resulting from Dilworth groundwater contamination; real risks are not likely to reach that limit. Only people who drilled a drinking water well in the most contaminated area (a small portion of the site) could experience the health problems discussed below.

Considering these relevant human exposure pathways, small amounts of the contaminants could be passed from the livestock to humans or from garden produce to humans. The estimated amounts of contaminants that could be ingested could cause adverse health effects if the Dilworth aquifer background groundwater were used to water domestic stock and irrigate gardens.

Iron and sulfate concentrations in the groundwater make the human health risks associated with the potential future use of this groundwater as a drinking water source unacceptable. However, such consumption is unlikely because of the water's unpleasant taste and odor, historical knowledge of poor water quality, and the presence of better quality water from other sources. Nevertheless, the estimated iron exposure level could be associated with elevated levels of iron (above normal values) in internal

organs such as the liver and pancreas. Elevated levels of iron in the body would lead to increased skin pigmentation and possibly cirrhosis of the liver. Although no drinking water wells are within a 2-mi (3-km) radius of the site, if the Dilworth groundwater were used as untreated drinking water for infants, sulfate levels could result in severe persistent diarrhea, potentially leading to dehydration, because infants are sensitive to sulfate toxicity. Laxative effects could be produced in adults who drink the water. Moreover, natural levels of sulfate present in the Dilworth groundwater near the site, and typically found in this area of Texas, are known to produce diarrhea in some individuals.

Human health would not be at risk from exposure to cadmium, cobalt, fluoride, or nickel through these pathways. Exposure to uranium may be of health concern due to its chemical toxicity and potential radiological damage. Chemical toxicity from exposure to uranium is not anticipated if humans drink the Dilworth groundwater. The additional cancer risk from radioactive uranium and longer-lived progeny of the uranium decay series, however, is at an unacceptable level of 1 in 1,000 over a lifetime. Any excess lifetime cancer risks associated with radionuclides due to human consumption of meat or milk from cattle that drank this water as their sole drinking water source are within an acceptable range as defined by the National Contingency Plan range, which is between 1 in 10,000 and 1 in 1,000,000.

The levels of manganese and arsenic observed in the natural Dilworth groundwater that is unaffected by the former mill tailings could lead to an increased risk of developing nervous system disorders resembling Parkinson's disease and/or skin cancer if the water were used as the sole source for a prolonged period. Naturally occurring manganese and arsenic, therefore, limit the potential use of groundwater in some areas as a source for drinking water.

An evaluation of the potential effects on livestock, if the Dilworth groundwater were used to water cattle, showed livestock would suffer no adverse health effects from drinking Dilworth groundwater. The Dilworth groundwater is also suitable for crop irrigation.

4.3.5.2 Deweesville/Conquista Aquifer

Although no livestock, domestic, or drinking water wells are screened in the Deweesville/Conquista aquifer within a 2-mi (3-km) radius of the site, the use of Deweesville/Conquista groundwater downgradient and farther than 2 mi (3 km) from the site has not been evaluated. The shallow groundwater at the Falls City site appears to have originated largely from past *in situ* mining and milling operations, and its use as a water supply is unlikely. Although the DOE has not determined whether the groundwater in the Deweesville/Conquista farther downgradient from the site is a usable water resource, it has not historically been used as a drinking-water source.

The background water quality in the Deweesville/Conquista aquifer was partially assessed before surface remedial action began. Sulfate, manganese, and uranium concentrations in the Deweesville/Conquista groundwater are high enough to cause serious adverse health effects. The health effects associated with exposure to sulfate, manganese, and uranium make the groundwater unsuitable for drinking, irrigating crops, or watering livestock (DOE 1995).

5.0 Groundwater Compliance Strategy Selection

The groundwater compliance strategies for the Falls City site and an explanation of the application of site-specific data to the groundwater compliance selection framework are presented below (Figure 5–1)

5.1 Compliance Strategy Selection Process

A health- and environmental risk-based framework for selecting site-specific compliance strategies is being applied to each UMTRA Project processing site. This compliance selection framework was developed in the UMTRA Groundwater PEIS. The framework enables the DOE to apply the same criteria to determine the groundwater compliance strategy at each site and to determine the appropriate compliance strategy.

A step-by-step approach is followed until one or a combination of three compliance strategies below is selected for a specific site.

- No remediation. Compliance with the EPA groundwater protection standards would be met without altering the groundwater or cleaning it up in any way. This strategy could be applied at sites with contamination at or below MCLs or background levels or at sites that have contamination above MCLs or background levels but qualify for supplemental standards or ACLs.
- Natural flushing. Allows natural groundwater movement and geochemical processes to decrease contaminant concentrations to levels within regulatory limits within a given time period. This strategy could be applied at sites where groundwater compliance would be achieved with natural flushing within 100 years, where effective monitoring and institutional controls could be maintained, and where the groundwater is not and is not projected to be a drinking water source.
- Active groundwater remediation. Requires application of engineered groundwater remediation methods such as gradient manipulation, groundwater extraction and treatment, and *in situ* groundwater treatment to achieve compliance with the standards.

5.2 Falls City, Texas, Compliance Strategy Selection

The groundwater compliance selection framework was applied to the uppermost aquifer characterized to be affected by activities at the processing site. Site conditions were used to determine that the no-remediation application of supplemental standards strategy is appropriate for the uppermost aquifer based on widespread ambient contamination and acceptable risks to human health and the environment (DOE 1995). Figure 5–1 shows how this target was selected.

Uppermost Aquifer Compliance Strategy

To protect groundwater and to achieve compliance with EPA groundwater standards under the UMTRA Surface Project (Subpart A of 40 CFR Part 192), the DOE proposed a narrative supplemental standard for Parcel A of the Falls City site and the disposal site. The supplemental standard for surface remedial action classified groundwater from the uppermost aquifer as limited use, based on widespread ambient contamination that could not be cleaned up with methods reasonably employed by public water systems.

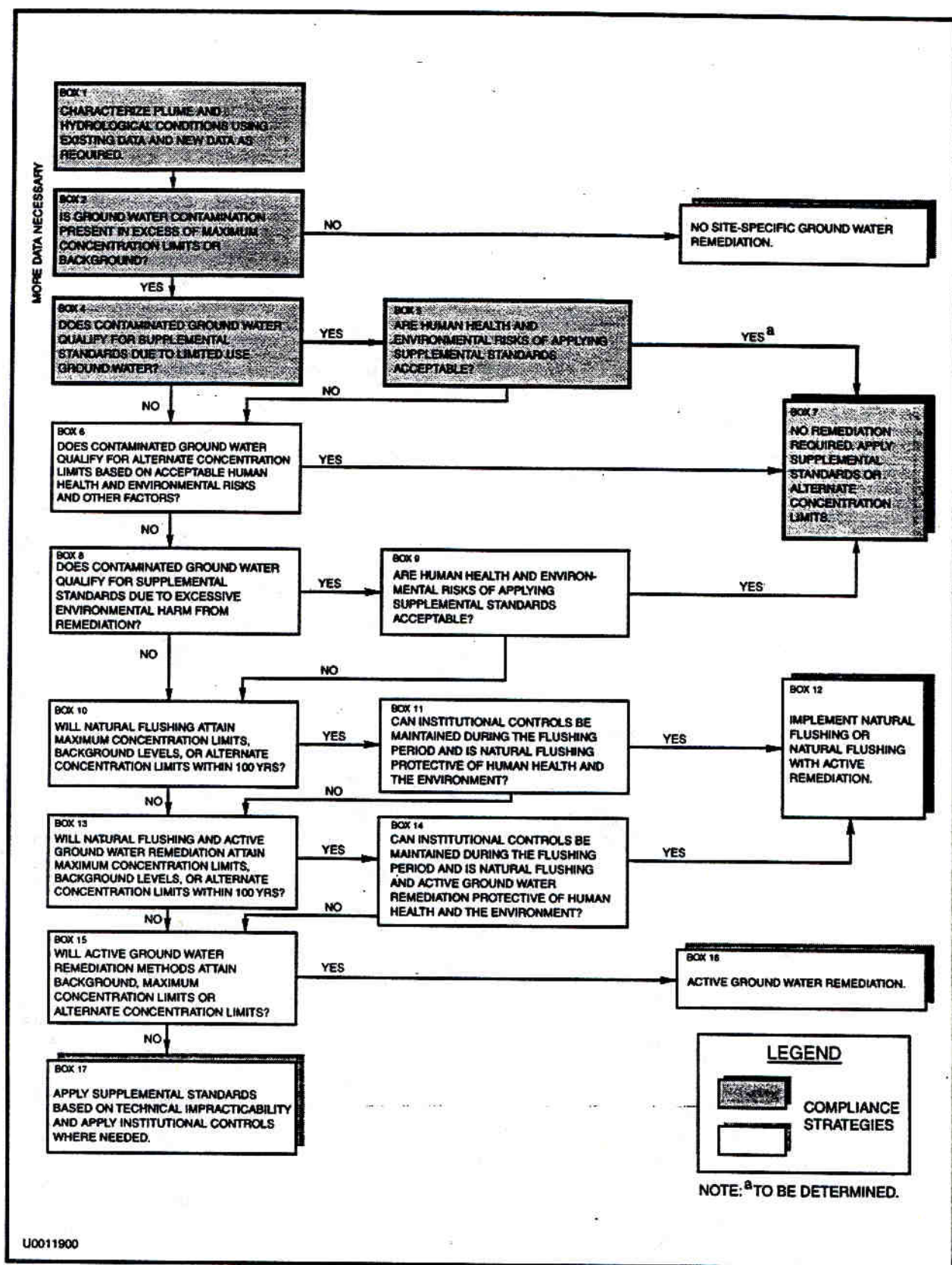


Figure 5-1. Framework Application of Contaminants of Potential Concern in the Uppermost Aquifers, Falls City, Texas, Site

To demonstrate existing widespread contamination in the uppermost aquifer, the DOE established background groundwater quality in the site vicinity (DOE 1992). Supplemental standards did not apply to Parcel B. However, there is no evidence that conditions are different in the uppermost aquifer in the vicinity of Parcel B. Background monitor wells were installed and monitored to demonstrate widespread ambient contamination of the uppermost aquifer in the vicinity of the disposal site. The DOE, NRC, and the state concurred with the supplemental standard application and agreed that the uppermost aquifer was limited use in 1992 (DOE 1992). Thus, the first step toward achieving compliance with the groundwater standards was to determine that widespread, ambient contamination persists in the uppermost aquifer in the site vicinity.

The second step was to determine whether compliance with the standards could still be achieved by applying supplemental standards based on limited use groundwater. Regulations define limited use groundwater as groundwater that is not a current or potential source of drinking water for the following three reasons: the concentration of total dissolved solids exceeds 10,000 mg/L; the groundwater contains widespread, ambient contamination, not caused by activities involving RRM from a designated processing site, that cannot be cleaned up with treatment methods reasonably employed by public water-supply systems; or the quantity of water available from a well is less than 150 gallons (570 liters) per day.

Hydrogeologic conditions and groundwater contamination conditions at the Falls City site have been characterized and are presented in Section 3.0. The background water in the uppermost aquifer still meets the criteria for limited use groundwater based on widespread, ambient contamination not caused by activities involving RRM from a designated processing site. The background water cannot be cleaned up with treatment methods reasonably employed by public water-supply systems. Making water from the uppermost aquifer potable would require multiple treatment technologies not typically used in Texas or in the region. Removing radionuclides from the groundwater will produce treatment plant wastes containing both hazardous and radioactive constituents. Also, treated groundwater from the uppermost aquifer would cost local residents considerably more than what they now pay for drinking water (DOE 1992b).

The DOE has determined from the data that supplemental standards are protective of human health and the environment, and that site-specific remediation is not required. Section 4.3.5 describes the limited uses of groundwater from the uppermost aquifer and the risk associated with exposure to contaminants of concern.

5.3 Deviations, Contingencies, and Decision Rules

The DOE's environmental restoration process generally, and the UMTRA Groundwater Project specifically, must make restoration decisions under conditions of inherent uncertainty. Uncertainties associated with limited site condition information and with uncertain remedial strategy performance are reduced to the extent practicable, in an effort to minimize time and resources spent on studying the problems and to expedite restoration activities. In developing this SOWP, the DOE maximized the use of existing and recently collected information to select a realistic remedial strategy. This SOWP developed and used a conceptual model to provide a foundation for compliance planning and action.

5.4 Future Monitoring Activities

Selected monitor wells located near the disposal cell will continue to be monitored as part of the Long Term Surveillance Monitoring Plan (LTSP). Additional monitor wells not currently identified in the Falls City LTSP could be added to the LTSP as best management practice to ensure protection of beneficial uses of the upper most aquifer. This decision has not been made. The LTSP will be modified, if necessary, to include future groundwater monitoring activities at the Falls City site.

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